ANNUAL REPORT
2006-07

ICAR

PDBC

PROJECT DIRECTORATE OF BIOLOGICAL CONTROL
BANGALORE, INDIA

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Front cover: *Encarsia flavoscutellum*, a parasitoid used successfully against the sugarcane woolly aphid

Back cover: *Mikania micrantha* infected with the Peruvian isolate of *Puccinia spegazzinii* imported for classical biological control of the weed

Hindi text

Mr. Satandra Kumar
Ms. Leena Singh

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1. PREFACE

Modern agriculture continues to face severe challenges due to pests, diseases and weeds, halting the growth in sustainable and profitable food production. Chemical pesticides are still heavily relied upon leading to several environmental and health problems for man and animals. The greatest impact is on the biodiversity of useful organisms, particularly the parasitoids and predators, which are often eliminated completely. The increasing use of chemical pesticides and weedicides are affecting the biodiversity and health of the soil.

Matching the vision of the Indian Council of Agricultural Research (ICAR), New Delhi, the Project Directorate of Biological Control (PDBC) endowed with a group of highly motivated and disciplined scientists ably supported by technical, administrative and supporting staff, continues to focus its efforts in development of biocontrol agents as potential components of ecology-based pest management. Keeping in mind the targeted agricultural growth rate of 4%, the PDBC through the All-India Coordinated Research Project (AICRP) on Biological Control with 16 cooperating and eight voluntary centres has developed robust biocontrol technologies during the past couple of decades. Biocontrol based pest management packages were developed, demonstrated and popularized among farmers and stakeholders. The research and development activity during the year 2006-07 focused on priority pests, diseases and weeds in agricultural and horticultural crops and significant success has been made in rice, cotton, sugarcane, pulses and oilseeds besides certain fruit and vegetable crops. The successful management of the sugarcane woolly aphid, *Ceratovacuna lanigera*, in the states of Maharashtra, Karnataka and Tamil Nadu by the deployment of the predators, *Dipha aphidivora*, *Micromus igorotus* and syrphids as well as the parasitoid *Encarsia flavoscutellum* is a landmark success of the PDBC. The large-scale adoption of biocontrol for rice pest management in the whole of the Adat Panchayat covering 3,000 ha in Kerala and sugarcane pests in Punjab and Harayana are a few example of useful outcome of the AICRP on Biological Control. This annual report documents the research output and outcome of the research efforts of the PDBC and AICRP. We welcome criticisms and suggestions from the readers which will be accepted with an open mind and humility.

Dr. Mangala Rai, Secretary, DARE & Director-General, ICAR, was a source of strength and support for which the biocontrol research community is grateful. Both Dr. Gautam Kalloo, the then Deputy Director-General, and Dr. S.P. Tewari the present Deputy Director-General (Crop Science) provided the much needed direction as well as encouragement and I thank them profusely. I am grateful to Dr. T. P. Rajendran, Assistant Director-General (Plant Protection), ICAR for his guidance and help in time of need in carrying out our programmes successfully,

I wish to place on record my appreciation to all the staff of the PDBC and the AICRP centres for their sincere efforts and hard work in executing the various programmes.

I thank Dr. B.S. Bhumannavar, Principal Scientist, Technical and Documentation Cell, Dr. P. Sreerama Kumar, Senior Scientist, Dr. Sunil Joshi, Senior Scientist, Mr. Satandra Kumar, Technical Officer and Ms. Leena Singh, Senior Research Fellow for their assistance in compiling and editing this report.

I hope this annual report would be useful to all the stakeholders involved in biological control and sustainable pest management.

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

2. निष्पादित सारांश

वर्ष 2006 - 07 के दौरान, जैविक नियंत्रण परियोजना निदेशालय (जै नि प नि) के साथ-साथ दस राज्य कृषि विश्व विद्यालयों और भारतीय कृषि अनुसंधान परिषद आधारित छः केन्द्रों के अतिरिक्त कई निजी स्वैच्छिक संगठनों के केन्द्रों पर अखिल भारतीय समन्वित अनुसंधान परियोजना (ए आई सी आर पी) के अन्तर्गत मौलिक और प्रायोगिक अनुसंधान, एक गहन अनुसंधान कार्यक्रम के तहत किए गए। इन गहन अनुसंधान कार्यक्रमो के माध्यम से फसलों के प्रमुख हानिकारक कीटों, रोगों और खरपतवारों के पर्यावरणीय प्रबंधन के अन्तर्गत जैव-नियंत्रण प्रौद्योगिकियों का विकास किया गया। फसलों में पैदा होने वाली नई-नई समस्याएं जैसे- *बी टी* कपास की फसल के चूषक कीटों तथा गन्ने के वूली माहूँ (रूईदार माहूँ) का पर्यावरणीय प्रबंधन और जैविक खेती में जैविक नियंत्रण का समेकितकरण इस कार्यक्रम के अन्तर्गत शामिल किया गया। अधिकांशतः परीक्षणों को वर्ष 2006 -07 के अन्तर्गत आने वाले तकनीकी कार्यक्रम के तहत सफलतापूर्वक किया गया और उनके परिणामो को यहाँ पर नीचे सारगर्भित किया गया है।

मौलिक अनुसंधान

जैविक नियंत्रण परियोजना निदेशालय, बेंगलोर

जीव-वर्गीकरण

भारत और नेपाल से *हेलीजिआ स्ट्रेमिनिआ* की एक नई सहोदर प्रजाति वर्णित की गई। *साइनोना, सिकम्नोडस, अपोलीनस, रहाईकोर्टेलिआ* और *क्रिप्टोलीमस* (कुछ भाग) का पुर्नावलोकन किया गया। *होर्निलोअस* की नई प्रजातियाँ कर्नाटक राज्य में पाई गई। भारतीय कोक्सीनेलिड्स पर हमारी वेबसाइट में पच्चीस नए फोटोग्राफ जोडे गए। साधारण कोक्सीनेलिडों की काम्पेन्डियम फेक्ट शीटों में तीन नई फेक्ट शीटों को जोड़ा गया।

आस्ट्रेलियन नेशनल इन्सैक्ट कलेक्शन (ए एन आई सी), सी एस आई आर ओ कीट विज्ञान, केनबरा, आस्ट्रेलिया से एकत्रित कोक्सीनेलिडों, विशेष रूप से आस्ट्रेलियन और ओरिएन्टल/भारतीय जीव-जन्तुओं के अध्ययन का प्रमुखता से अध्ययन किया गया।

ट्राइकोग्रामा और *ट्रायकोग्रामाटॉयडिआ* का जीव-वर्गीकरण अध्ययन प्रारम्भ किया गया। धान की फसल में *काइलो इन्फसकटेलस* पर *ट्राइकोग्रामा फ्लेन्डेर्सी* और *ट्राइकोग्रामा किलोनिस* ; *स्किरपोफेगा इन्सर्टूलस* पर *ट्राइकोग्रामा जेपानिकम* और हेस्पेरिडे पर *ट्राइकोग्रामा हेस्पेरिडिस* एकत्रित किए गए तथा अरहर की फसल में *हेलीकोवर्पा आर्मिजेरा* पर *ट्राइकोग्रामाटॉयडिआ आर्मिजेरा* एकत्रित किए गए ; फील्ड बीन (सेम) की फसल में, *लेम्पिडस बोएक्टिअस* पर *ट्रा. किलोनिस* एकत्रित किए गए तथा इन संवर्धनों को *कोरसेरा सीफेलोनिका* के अंडों पर पाला गया। *ट्राइकोग्रामा* की एक प्रजाति को स्फिन्जिडिए और दूसरी प्रजाति को ब्रूकीड् के अंडों से एकत्रित किया गया।

प्राकृतिक शत्रु कीटों का उपोद्घात

हेट्रोसिल्ला स्पिनुलोसा द्वारा *मिमोसा डाईप्लोट्रिका* का जैविक नियंत्रण करने के लिए, मार्च 2007 में आयात करने के लिए अनुमति प्राप्त की गई। *ट्राइकोग्रामा सिम्बलिडिस, ट्रा. प्रेटिओजम, ट्रा. इवेनिसेन्स, ट्रा. एम्ब्रियोफेगम* और *ट्रा. केकोइसीए* को आयात करने के लिए अभ्यावेदन दिया गया है।

क्रोमोलीना ओडोरेटा की तना गाँठ मक्खी को जुलाई 2005 के दौरान खेत में छोड़ा गया था जो कि दो जगह के क्षेत्रों में पूरी तरह से स्थापित हो गयीं हैं और सर्दी तथा गर्मी की दो कठिन ऋतुओं के बाद भी सफलतापूर्वक कार्य कर रहीं हैं। गाँठ मक्खी की सघनता टाटागुनी गाँव में बहुत अधिक जबकि गाँधी कृषि विज्ञान केन्द्र में कम पाई गई। पिछले एक वर्ष के दौरान इन गाँठ मक्खियों का विस्तार, गाँधी कृषि विज्ञान केन्द्र

में एक किलोमीटर तक जबकि टाटागुनी गाँव में दो किलोमीटर तक फैला पाया गया।

परजीवी कीट और परभक्षी कीट

एनकार्सिआ फलेवोस्कूटेलम द्वारा परजीवित माहूँ कीटों में कायरूपान्तरण परिवर्तन देखा गया। इनके ऊपर ऊनी या रूईदार परत कम तथा गहरे धब्बे दिखाई पडें। इससे माहूँ के परजीवीकरण होने का अनुमान होता है और इन अनुमानित माहूँओं में से 70% परजीवी कीट बाहर निकलते हैं।

डाइफा एफिडिवोरा, *माइक्रोमस इगोरोटस*, *ए. फ्लेवोस्कूटेलम* और *सीरेटोवेक्यूना लेनिजेरा* से डी एन ए अर्क निकाला गया, जिससे प्रत्येक के आई टी एस विस्तार की पहचान की जा सके। इनमें से केवल *ए. फ्लेवोस्कूटेलम* में लगभग 700 बी पी पाए जाने की पहचान की जा सकी।

बेंगलोर और इसके आसपास के क्षेत्रों में दिसंबर, 2006 और फरवरी 2007 के दौरान अरहर की फसल से तथा कोयम्बटूर में दिसंबर माह के दौरान कपास पारिस्थितिक तंत्र से *हे. आर्मिजेरा* के संक्रमित लारवों से *केम्पोलेटिस क्लोरीडिए* के कोकुन प्राप्त किए गए। मक्का (मार्च-अक्टूबर 2006), गेंदा (दिसंबर 2006), सूरजमुखी (जनवरी 2007), और गुलाब (फरवरी-मार्च 2007) की फसलों से *ओरिअस टेन्टिलस* की फसल से बेंगलोर में एकत्रित किया जा सका और इसको पुणे में भी सूरजमुखी की फसल से एकत्र किया जा सका। सितंबर-अक्टूबर, 2006 के दौरान *ब्लाप्टोस्टेथस पेलेसेन्स* को मक्का की फसल से और फरवरी-मार्च 2007 के दौरान अंगूर और गुलाब की फसल से एकत्र किया गया।

के. क्लोरिडिए को दो बार छोडने के बाद, उपचारित प्लॉट में 0.95 सूँडी प्रति पौधा और अनुपचारित प्लॉट में 1.35 सूँडी प्रति पाया गया। गई। अनुपचारित प्लॉट से एकत्रित सूँडी केवल 0.1% ही परजीवित पाई गई जबकि उपचारित प्लॉट से एकत्रित सूँडी 22 S तक परजीवित पाई गई। खेत में परजीवी कीट को चार बार छोड़ने के बाद चने की अनुपचारित फसल में फलियों की क्षतिग्रस्तता 28.7 प्रतिशत जबकि उपचारित फसल में केवल 3.24 प्रतिशत ही पाया गया।

साईटोट्रोगा सीरीएलेल्ला के अंडों पर *ओ. टेन्टेलिस* को पालना अति उत्तम पाया गया।

ओ. टेन्टेलिस को चार विभिन्न तापक्रमों 20, 24, 28 और 32^0 से.ग्रे. पर पालकर उनकी जननक्षमता का अध्ययन किया गया। इस कीट की प्रजनन दर 20^0 से.ग्रे. की अपेक्षा 24, 28 और 32^0 से.ग्रे. पर अधिक पाई गई। परिकल्पित मादाओं की दूसरी पीढ़ी निकलने की दर 28^0 से.ग्रे. पर अधिक पाई गई और इस तापक्रम पर उनकी प्रजनन एवं, अन्तर्जात दर बढ़ी तथा साप्ताहिक गुणन दर भी अधिक पाई गई, इससे *ओ. टेन्टेलिस* को पालने के अनुकूल तापक्रम का अनुमान लगता है।

वेयर हाऊस पायरेट बग, *जाइलोकोरिस फ्लेविपस* को *कोरसेरा सीफेलोनिका* के अंडों पर सफलतापूर्वक गुणित किया गया। इसका एक निम्फ औसतन 3.4 अंडे प्रतिदिन तथा प्रौढ़ कीट 10.3 अंडे प्रतिदिन खाता है। प्रौढ़ नर कीट का औसत जीवन काल 10.8 दिन और मादा कीट का 28 दिनों पाया गया। एक मादा अपने जीवन काल में 62 अंडे देती है।

ब्ला. पेलीसेन्स को जब *कोरसेरा सीफेलोनिका* के अंडों पर पाला गया तो इनकी प्रजनन दर, परिकल्पित मादा की दूसरी पीढ़ी और साप्ताहिक गुणन दर महत्ता *साईटोट्रोगा सीरीएलेल्ला* पर पालने की अपेक्षा अधिक पाई गई, इससे यह प्रदर्शित होता है कि *ब्ला. पेलीसेन्स* को *कोरसेरा सीफेलोनिका* के अंडों पर आसानी से पाला जा सकता है।

इसकी प्रजनन दर 28^0 से.ग्रे. पर अत्यधिक (65.05) पाई गई। इनकी 24 और 28^0 से.ग्रे. पर समापक दर अधिक तथा अन्तर्जात दर महत्ता अत्यधिक एवं इन तापक्रमों पर इनके द्विगुणित होने के लिए कम समय लगा। इस कीट की 28^0 से.ग्रे. तापमान पर परिकल्पित मादा की दूसरी पीढ़ी और साप्ताहिक गुणन दर महत्ता अधिक पाई गई, इससे यह प्रदर्शित होता है कि *ब्ला. पेलीसेन्स* को 28^0 से.ग्रे. के नियत तापमान पर प्रभावपूर्ण ढंग से गुणित किया जा सकता है।

ब्ला. पेलीसेन्स को स्पाइडर माइट के प्रति प्रयोगशाला और नेट हाऊस में आकलन किया गया। प्रौढ़ कीटों की अपेक्षा निम्फ, माइटों को भूक्खडों की तरह खाते हैं। *ब्ला. पेलीसेन्स* के निम्फों को भिंडी के पौधों पर स्पाइडर माइटों के प्रति छोडा गया। अनुपचारित पौधों की अपेक्षा उपचारित पौधों में प्रति पत्ती

माइटों की 78% तक कमी पाई गई।

ओरिअस टेन्टिलस के निम्फ, प्रौढ़ नर और मादा *स्किरटोथ्रिप्स डोरसेलिस* को क्रमशः 42, 105 और 211 की दर से भक्षण कर पाए। जब *ओ. टेन्टिलस* के निम्फों को *स्किरटोथ्रिप्स डोरसेलिस* द्वारा ग्रसित क्षेत्रीय दशाओं में गुलाब पर छोड़ा गया तो कलियों/फूलों पर थ्रिप्स का ग्रसन 50 से 77% कम पाया गया।

हे. आर्मिजेरा के न्यूक्लियर पोलीहेड्रोसिस विषाणु

हिअर एन पी वी का अनुलम्बन बढ़ाने के लिए, सभी अन्य सहायक गुणवर्धकों के परीक्षण में से शीरा 5% + टिनॉपाल 0.2% + लैंप ब्लैक 0.1% को सर्वश्रेष्ठ पाया गया। इसके पश्चात कच्ची चीनी (5%) + टिनॉपाल (0.2%) का किसान के खेत में टमाटर की फसल पर *हे. आर्मिजेरा* के प्रति *हिअर* एन पी वी नियमन के मूल्यांकन का अध्ययन किया गया, इस अध्ययन में पाया गया कि यह विषाणु हानिकारक कीट को प्रभावी रूप से नियंत्रित करते हैं और फलों की क्षति में कमी तथा लारवों की मृत्यु दर भी बढ़ाते है।

हिअर एन पी वी को गीला करने योग्य पाउडर नियमन को सुरक्षित रखने के लिए फ्रीज और कमरे के तापक्रम पर अध्ययन में फ्रीज में रखे जाने की दशा में दोनो प्रकार के नियमनों के एल सी$_{50}$ मात्रा पर विभन्न समयों के लिए फ्रीज में संग्रहित करने पर कोई विशेष अंतर नहीं दिखाई दिया। जबकि कमरे के तापक्रम पर विषाणुओं के नियमनों द्वारा सात माह संग्रहण के बाद एल सी$_{50}$ मात्रा महत्वपूर्ण रूप से अत्यधिक दिखाई दी।

हवा निकालकर, गीला करने के योग्य पाउडर में नाइट्रोजन के साथ मिलाकर पैक नियमन ने कमरे के तापक्रम पर पूरे नौ महीनों के संग्रहण तक नियमन की एल सी$_{50}$ महत्ता में विषाणु क्षमता कमी नहीं दर्शाई। कमरे के तापक्रम पर नौ महीनों के बाद गीला करने योग्य पाउडर के साथ मिलाकर और हवा निकालकर पैक करने वाले नियमन की अपेक्षा अनियमन विषाणु निस्पंदन की एल सी$_{50}$ मात्रा 2.1 गुणा अधिक हो गई। संग्रहण समय बढ़ने के साथ एल टी$_{50}$ मात्रा अधिकाधिक बढ़ती है। नौ महीनों के संग्रहण के पश्चात अनियमन विषाणुओं की संख्या 129.7 (फ्रीज दशा में) और 167.2 घन्टे (कमरे के तापक्रम पर) पाई गई। कमरे के तापक्रम पर नौ महीनों के संग्रहण के पश्चात, हवा निकालकर, गीला करने योग्य पाउडर में नाइट्रोजन के साथ मिलाकर पैक नियमन की एल टी$_{50}$ मात्रा बहुत कम (145.7 घन्टे) पाई गई।

कीट कोशिकाओं लाईन्स का स्थापन

एन पी वी के *इन विट्रो* क्लोनिंग के लिए *स्पो. लिट्यूरा* और *हे. आर्मिजेरा* के अंडों के भ्रूणों की मुख्य कोशिका धाराओं में ये स्थापित हो गए। गुणित कोशिकाएँ 80% समागम अवस्थानित हुई और कोशिकाओं की जीवनक्षमता का निर्धारण किया गया।

बेसीलस थ्यूरिन्जिएन्सिस के देशी विभेदों का पृथक्करण और विशेषताएँ

निर्दिष्ट पृथक्करणों जैसे पी डी बी सी-बी टी 1 और पी डी बी सी-बी एन जी बी टी 1 *प्लूटेल्ला जाइलोस्टेल्ला* (पातगोभी के पत्ती जैव निर्धारण) और *हे. आर्मिजेरा* (आहार जैव निर्धारण पर) के प्रति तीन विभिन्न विलयनों द्वारा 100% घातकता पैदा करते हैं। पृथक्करणों का विषैलापन एच डी 1, सी 21, एच 21 और डाईपेल के समान आदर्श पाया गया।

काइलो पारटीलस, *सीसेमिआ इन्फेरेन्स* और *सानिआ सिन्थिआ रिसिनी* (ऐरी रेशमी कीट) कीटों के प्रथम निरूपीय लारवों के प्रति *बेसलीलस थ्यूरिन्जिएन्सिस* को सौ प्रतिशत घातक पाया गया। यद्यपि *सीसेमिआ इन्फेरेन्स* और *सानिआ सिन्थिआ रिसिनी* (ऐरी रेशमी कीट) के तीसरे निरूपीय लारवों पर कम घातकता दर्शाई।

आदर्श प्रोटीन भार आण्विक के 10% जैल में 75 वॉल्ट पर पी डी बी सी -बी टी 1, बी एन जी टी 1 और एच डी 1 के नमुनों के साथ एस डी एस - पी ए जी ई विश्लेषण किया गया। सभी नमूनों में 30 के डी ए, 25 के डी ए और 17 के डी ए आण्विक भार प्रोटीन पाई गई। एच डी-1 विभेद में 36 के डी ए और 13 के डी ए प्रोटीन पट्टी भी देखी गई जो कि अन्य लाईनों में नहीं पाई गई। बी एन जी टी 1 में अनोखे रूप में अन्य पट्टियां 60 के डी ए, 30 के डी ए, 25 के डी ए और 17 के डी ए दर्शाते हैं।

पी डी बी सी- बी टी 1, बी एन जी टी 1 और एच डी 1 का डी एन ए मार्कर आदर्श आण्विक भार के साथ अगारोज जैल इलैक्ट्रोफोरेसिस किया गया। डी

एन ए का 5804 बी पी से 7421 बी पी तक विभिन्न कुल आकार उपस्थित पाए गए।

आंतर्जीवी जीवाणुओं का अध्ययन

बेसीलस मेगाटेरिअम, *बे. सर्कुलेन्स*, *बेसीलस स्पे.*, *इर्विनिआ हर्बिकोला*, *एन्टेरीबेक्टर ऐग्लोमीरान्स*, *स्यूडोमोनाज ऐईरूजिनोसा*, *क्रिप्टोकोकस एल्बिडस*, *स्यूडोमोनाज फ्लुरेसेन्स* (19), *स्यू. पुटि्टडा* (1), *स्यूडोमोनाज स्पे.*, *बे. सब्टिलिस* (2), *बे. मेगाटेरिअम* (फास्फेट विलायक) और *फ्लुरेसेन्ट स्यूडोमोनाड्स* (28) आंतर्जीवी जीवाणुओ को जै. नि. प. नि. के संवर्धन संग्रहण में देखरेख की जा रही है।

काइटिनेज एक्सप्रेशन के लिए *बेसीलस स्पे.*, *स्यूडोमोनाज फ्लुरेसेन्स* और *बेसीलस सब्टिलिस* को उत्तम पाया गया।

आठ विभिन्न प्रतिजीवियों को रखने वाली ऑक्टोडिस्क (हाईमिडिया) का विभिन्न सान्द्रताओं का प्रयोग करके पादप आंतर्जीवी जीवाणु का प्रतिजीवी प्रतिरोधक प्रतिरूप विकसित किया गया। पच्चीस जड़ ऊतकों का परीक्षण किया गया उनमें से 10 परीक्षणों में क्रमशः *बे. मेगाटेरिअम* और ग्यारह परीक्षणों में *बेसीलस स्पे.* पाए गए। जबकि पत्ती ऊतक के तीन नमूनों में *बे. मेगाटेरिअम* और *बेसीलस स्पे.* पाए गए।

अनुपचारित पौधों से तुलना करने पर पाया कि सभी जीवाणु उपचारित पौधों में काइटिनेज सक्रियता काफी अधिक थी। *बेसीलस मेगाटेरिअम* उपचारित पौधों के ऊतकों में काइटिनेज सक्रियता 2.53 यू/ग्रा जबकि अनुपचारित पौधों में यह केवल 1.59 यू/ग्रा पाई गई। *बेसीलस स्पे.* द्वारा उपचारित पौधों ने भी ए-1, 3-ग्लूकोनेज सक्रियता अत्यधिक (2.69 यू/ग्रा) दर्शाई। इसके बाद *स्यू. फ्लूओरेसेन्स* द्वारा अधिक सक्रियता दिखाई।

आंतर्जीवी *बेसीलस स्पे.* द्वारा ट्रिप्टिक सोया अगार पर अत्यधिक अवरोधन (50%) और *स्यू. फ्लूओरेसेन्स* (रहाईजोस्फेयर पृथक) द्वारा सबसे कम (25%) प्रर्दशित किया गया। आलू डेक्सट्राज अगार पर सभी जीवाणुओं का अवरोधन कम और आंतर्जीवी *बेसीलस स्पे.* में सबसे अधिक 25% देखा गया। *फ्यू. सोलेनाई* के प्रति आंतर्जीवी *बेसीलस स्पे.* में अत्यधिक 50% अवरोधन देखा गया और इसके बाद आंतर्जीवी *ईरविनिआ हर्बिकोला* द्वारा 37.50% अवरोधन देखा गया। आलू डेक्सट्राज अगार पर सभी जीवाणुओं का अवरोधन कम और यहाँ पर भी आंतर्जीवी *बेसीलस स्पे.* में सर्वाधिक 33.3% अवरोधन देखा गया। ट्रिप्टिक सोया अगार पर *बेसीलस स्पे.* और *ईरविनिआ हर्बिकोला* द्वारा *ब. डहलिए* का अवरोधन 41 से 48% तक, जबकि आलू डेक्सट्राज अगार पर य सभी 23 से 34% तक अवरोधन दर्शाते हैं।

फ्यूजेरियम वेसिनफैक्टम के प्रति *बे. सबटिलिस* का मिथेनोल अर्क सर्वाधिक अवरोधन (38%) जबकि *स्यू. फ्लूओरेसेन्स* के अर्क द्वारा 36% अवरोधन देखा गया। *फ्यूजेरियम सोलेनाई* के प्रति *बे. सबटिलिस* के अर्क द्वारा फिर से सर्वाधिक अवरोधन (37%) जबकि *बेसीलस स्पे.* और *फ्यू. फ्लूओरेसेन्स* के अर्कों द्वारा 34% अवरोधन देखा गया। *वर्टिसिलियम डहलिए* के प्रति *बे. सबटिलिस* के अर्क द्वारा पुनः अत्यधिक (30%) अवरोधन पाया गया।

दो धब्बेदार माइट, *टेट्रानिकस अरटीके* के प्रति *हिर्सुटेल्ला थोम्पसोनाई* के परवर्ती उपापचय में ऊष्मक नियंत्रण में चार दिनों में माइट के 64.4% निम्फ मरे पाए गए।

ग्रीन हाऊस में गुलाब के पौधों पर *हि. थोम्पसोनाई* उपापचयज का चौथे दिन छिड़काव करने पर *टे. अरटींके* की संख्या को सफलतापूर्वक बहुत कम किया जा सका। उपचार के आठ दिनों के बाद जीवित माइटों के आक्रमण में 48.3% तक की कमी पाई गई।

ग्रीन हाऊस दशाओं में *ब्युवेरिआ बेसिआना*, *हिर्सुटेल्ला थोम्पसोनाई*, *लिकेनिसीलीअम सेलीओटे* और *मेटारहाईजिअम एनाईसोप्लिए* के साथ दो गुणवर्धनों को जैसे छितराने योग्य ठंडे पानी वाला स्टार्च (0.2% अन्तिम सान्द्रता) और ग्लिसरोल (1% अन्तिम सान्द्रता)

भिंडी की फसल पर *टे. अरटींके* की संख्या में कमी कर देती है। माइट की संख्या को 85.2% तक कम करने के लिए *हि. थोम्पसोनाई* को सर्वोत्तम पाया गया।

कवक प्रतिरोधी

उत्पादन माध्यम में 3% सान्द्रता वाला ग्लिसरोल

मिलाने पर प्रजनक कणों की जीवन क्षमता (2.6x10^{11}/ग्रा.) को आठ महीनों तक बढ़ा कर रखा जा सकता है जबकि बिना ग्लिसरोल मिलाये माध्यम को कम समय के लिए (10^6/ग्रा., छःमहीनों के लिए) रखा जा सका।

30 या 60 मिनट तक 30° से.ग्रे. ताप विक्षोभ करने पर शुष्कीकरण सहिष्णु प्रेरित और इसको सुरक्षित रखने के समय को एक माह और अधिक बढ़ा देती है। यद्यपि 6 माह के दौरान यदि जलक्रिया में अत्यधिक कमी होती है तो प्रजनक कण शुष्कीकरण को सहिष्णु नहीं होते और इनकी जलक्रिया एकदम से कम हो जाती है। ताप विक्षोभ से इनके रखने के समय को एक महीने के लिए और अधिक बढ़ाया जा सकता है। ताप विक्षोभ के उपचार के साथ करने से इसकी जल क्रिया को बरकरार रखा जा सकता है।

प्रारंभिक नमी की 8 या 10% पर संग्रहण करने की तुलना में प्रारंभिक नमी 15% रखने पर प्रजनक कणों की जीवन क्षमता को लम्बे समय तक रखने में सहायक पाया जाता है जबकि 20% नमी पर संग्रहित प्रजनक कणों में संक्रमण अत्यधिक संख्या में रखा जा सका। इनको पैकिंग करने की तीन विधियां जैसे सामान्य पैकिंग, अतिरिक्त हवा निकालकर पैकिंग और नाइट्रोजन मिलाकर की गई पैकिंग करके नियमनों को विभिन्न प्रारम्भिक नमी स्तरों पर संग्रहित किया गया परंतु उनके प्रजनक कणों की जीवनक्षमता पर कोई विशेष अन्तर नहीं देखा गया।

द्रवीय किण्वन से जैव द्रव्यमान का प्रयोग करके बनाए गए नियमनों की अपेक्षा अधोस्तर के बिना बनाए गए ठोस अधोस्तर (एस एस डी) कोनॉयडल नियमनों को आसानी से अधिक समय के लिए रखा जा सकता है। यहाँ तक देखा गया है कि 8 महीनों के बाद भी एस एस डी से बने नियमनों के प्रजनक कणों की क्षमता 10^8 सी एफ यू/ ग्राम पाई गई। ये नियमन न्यून जलक्रिया सहिष्णु पाए गए।

तीनों प्रकार की पैकिंग विधियों के 5 महीनों के दौरान संग्रहित किए *ब्यू. बेसिआना* की सी एफ यू संख्याओं और तीनों के नमी परीक्षणों में कोई विशेष अंतर दिखाई नहीं दिया।

सी एम सी संशोधित माध्यम पर *ट्राइकोडर्मा विरिडिए* स्तरों जैसे टी वी-4, टी वी-23, टी वी-25, टी वी-29, और टी वी-30 पृथक्करणों ने अच्छी वृद्धि दिखाई। पी सी डब्लयू पर, टी वी-29 ने सबसे अधिक वृद्धि (113 मिग्रा./ 50 मिली.) इसके बाद टी वी 25 और टी वी 28 (दोनों में 61 मिग्रा./ 50 मिली.) जबकि टी वी 31 और टी वी 32 पृथककरणों द्वारा बहुत कम वृद्धि दर्शाई। टी वी-32 ने सी एम सी संशोधित द्रवीय माध्यम में एन्डो 1, 4-ग्लूकोनेज सक्रियता अत्यधिक प्रदर्शित की, इसके बाद टी वी - 30, टी वी - 14, टी वी - 11 और टी वी - 31 ने सक्रियता दिखाई। ए-1,3-ग्लूकोनेज के उत्पादन के संबंध में टी वी - 13 और टी वी - 14 ने सक्रियता दिखाई इसके पश्चात टी वी - 34, टी वी - 31, टी वी - 32, टी वी - 36, टी वी - 5 और टी वी - 30 ने सक्रियता दिखाई।

पादप रोगाणु कोशिका भित्ति संशोधित माध्यम में टी वी - 32 और टी वी - 35 पृथक्करणों ने 1,4-ग्लूकोनेज सक्रियता अत्यधिक दिखाई इसके पश्चात टी वी - 25, टी वी - 29, टी वी - 23 और टी वी - 31 ने सक्रियता दिखाई। टी वी - 34 में ए-(1,3)-ग्लूकोनेज की अधिक सक्रियता देखी गई।

सी एम सी या पादप रोगाणुओं की कोशिकाभित्ति सुधरे माध्यम में *ट्रा. विरिडिए* के पृथक्करणों के द्वारा प्रोटीन प्रोफाईल के एक्सट्रा सेलुलर प्रोटीनों के स्राव को प्राप्त करने के लिए एस डी एस- पी ए जी ई विश्लेषण का प्रयोग किया गया। पहले से अभिलेखित प्रोटीनों के हाल में किए गए अध्ययन में पाई जाने वाली ग्लूकोनेज सक्रियता का निरीक्षण जैल इलैक्ट्रोफोरेसिस सक्रियता की सहायता से पुष्टि करने की प्रक्रिया जारी है।

टी वी एस- कालीकट, टी वी एस -सी पी सी आर आई और पी डी बी सी के तीन पृथक्करणों टी वी एस-7, टी वी एस -9 और पी डी बी सी 12 पृथक्करणों में काइटिनेज उत्पादन अन्यों की अपेक्षा बहुत अधिक पाया गया।

जब *ट्रा. विरेन्स* संवर्धन की जैवक्षमता को *फ्यू. सिसेरी* के प्रति जाँचने के लिए प्रयोग किया गया तब टी वी एस 1, टी वी एस 3 और टी वी एस-कालीकट पृथक्करणों के टॉल्क नियमनों से मृदा उपचार करने पर अत्यधिक अंकुरण और जड़ तथा कोंपलों की लम्बाई के अलावा जडों का विस्तार अधिक पाया गया। यद्यपि

किन्हीं भी पृथक्करणों से उपचारित सभी पौधों में मुरझान रोग (विल्ट रोग) के लक्षण दिखाई नहीं पडे। अंकुरण और जडों के फैलाव के आधार पर टी वी एस 1 और टी वी एस 3 श्रेष्ठ पाए गए।

कीटरोगाण्विक सूत्रकृमि

सूत्रकृमियों को अन्य केन्द्रों या अनुसंधान केन्द्रों को भेजने के लिए स्पाँज विधि सर्वोत्तम पाई गई, इसके द्वारा *स्टेईनर्नेमा* स्पे. में 3-4 महीनों तक 90% और *हेटेरोरहरब्डिटिस* स्पे. में 2 महीनों तक 85% तक जीवक्षमता पाई गई।

ई पी एन का दानेदार नियमन मृदा उपचार के प्रयोग के लिए उत्तम पाया गया। लगभग 15 संयोजनों में से, दो संयोजन *हेटेरोरहरब्डिटिस* की संख्याओं को 60 दिनों के लिए, चार संयोजन 30 दिनों के लिए, तीन संयोजन 45 दिनों के लिए और दो संयोजन 15 दिनों के लिए अनुपोषक प्रभावी पाए गए। *स्टेईनर्नेमा* की संख्याओं (60%) को 30 दिनों के लिए अनुपोषक प्रभावी पाए गए।

ई पी एन को खेत में प्रयोग करने के लिए कडावर नियमन श्रेष्ठ पाया गया क्योंकि *स्टे. कार्पोकेप्से*, *स्टे. अब्बासी* और *हे. इन्डिका* के विशेष नियमनों के प्रयोग करने से उनकी अगली पीढ़ीयाँ दो महीनों तक ग्रसित रहती हैं और यह *हे. इन्डिका* में सबसे अधिक है।

ई पी एन नियमनों को पैक करने के लिए 75% वेक्यूम करके या 75% नाइट्रोजन गैस के साथ पैकिंग करना, 100% वेक्यूम पैकिंग करने की विधि से श्रेष्ठ है। ई पी एन नियमनों की जल सक्रियता परिवर्तन नहीं किया, परिणाम स्वरूप संग्रहित नियमनों को विभिन्न संवाहक पदार्थों के साथ तीन महीनों में उपयोग किया गया।

ई पी एन का वैक्स मौथ लारवों पर इन विवो उत्पादन के लिए तापक्रम की अपेक्षा आर्द्रता नियमित करके और *स्टे. कार्पोकेप्से* और *हे. इन्डिका* की मात्रा क्रमशः 50 और 100 संक्रमित ज्यूवेनाईल्स की दर से खेत में प्रयोग अत्यधिक अनुकूल पाई गई।

स्टे. कार्पोकेप्से और *हे. इन्डिका* दोनों के लिए बलुई मिट्टी अनुकूल पाई गई। चिकनी और दुमट मिट्टी सूत्रकृमियों की दोनों प्रजातियों के लिए अनुकूल नहीं पाई गई। सामान्यतः *स्टे. कार्पोकेप्से* को सभी प्रकार की मृदा के लिए अनुकूल कर दिया।

पादप परजीवी सूत्रकृमियों का जैविक नियंत्रण

बुआई के पूर्व *पेसीलोमाइकस लिलेसीनस* इसके बाद *ट्राइकोडर्मा हरजिएनम* द्वारा 10^9 बीजाणु/ गमला (2 किग्रा. मिट्टी) की दर से उपचारित करने पर कपास की फसल में *फ्यूजेरिअम* - रेनिफॉर्म सूत्रकृमि द्वारा होने वाली मुरझान रोग से होने वाली नवोद्भिदों की क्षति को 8% तक कम कर देता है।

आर्थोबोट्रायस ओलिगोस्पोरा का टॉल्क आधारित नियमन (पी डी बी सी-ए ओ 1) प्रयोग करने से टमाटर और लोबिया की फसल में सूत्रकृमि संक्रमित मृदा में क्रमशः जड़ ग्रन्थि और वृक्काकार सूत्रकृमियों के द्वारा होने वाले जड़ संक्रमण को कम करता है। पेट्री प्लेअ में की गई जाँच परीक्षण में ई पी एन ज्यूवेनाईल्स द्वारा 8-11% तक परजीवीकरण पाया सिसे प्रदर्शित करता है कि *आ. ओलिगोस्पोरा* ई पी एन के लिए सुरक्षित है।

अरहर की फसल में *पे. लिलेसिनस* और *पो. क्लेमॉयडोस्पोरिआ* के टॉल्क नियमन को 20 किग्रा./ एकड की दर से डालने पर अनुपचारित प्लॉट की तुलना में अरहर के सूत्रकृमियों की 48-59% तक कमी और अरहर की उपज में 18-21% प्रति प्लॉट वृद्धि हुई, ये परीक्षण त कृ वि वि, कोयंबतुर और आ कृ वि वि, जोरहाट में किए गए।

प्राकृतिक शत्रु कीटों का अध्ययन

अनोपचारित की तुलना में, 6 घन्टे वाले उपचारित कपास की पत्तियों के द्रव्य अंश *ट्रा. किलोनिस* के प्रौढ़ों को *कोरसेरा सीफेलोनिका* के अंडों पर अत्यधिक परजीवीकरण के लिए आकर्षित करता है। मटर की पत्तियों पर, *हे. आर्मिजेरा* के अंडों पर *ब्लाप्टोस्टेथस पेलेसेन्स* अंड परभक्षी कीट की भक्षण क्षमता का अध्ययन किया गया। सर्वाधिक 90% भक्षण धुली हुई (उपचारित) नमी सहित पत्तियों पर और सबसे कम भक्षण बिना धुली (अनुपचारित) नमी रहित पत्तियों पर पाया गया। जब बिना धुली नमी रहित पत्तियों पर 7 दिन आयु वाले निम्फ छोडे गए तो परभक्षी अधिक मरे और जब 10 दिन आयु वाले निम्फ और प्रौढ़ों को छोडा गया तो परभक्षी बहुत कम मरे पाए गए। धूली हुई पत्तियों पर परभक्षी कीटों की घातकता कम पाई गई।

भिंडी और टमाटर की पत्तियों के रसद्रव्यों की परभक्षी कीट के प्रति नकारात्मक परस्पर अन्तःक्रिया नहीं पाई गई। यद्यपि, मटर ट्राइकोम्स द्वारा मालिक अम्ल और दो केटोन्स, 2- ट्राईडिकेनोन तथा 2- अंडिकेनोन पाए गए जो कि अपने विषैलेपन के लिए जाने जाते हैं।

पातगोभी, अरण्डी, गन्ना और ओसीमम की पत्तियों के प्रमुख वाष्प द्रव्यों की पहचान की गई। पन्द्रह पादप वाष्प द्रव्यों के जैव विश्लेषण के मूल्यांकन में पाया गया कि 0.05 और 0.1% सान्द्रताओं वाले मूल्यांकन किए गए सभी यौगिकों के लिए *ट्रा. किलोनिस* के प्रौढ़ सकारात्मक प्रतिक्रिया दर्शाते हैं।

केरिओफिलेन, पाईनेने और लिनालूल का 0.1 :0.1:0.1 अनुपात वाला मिश्रण *क्रा. कारनिआ* को अत्यधिक अंडनिक्षेपण के लिए उत्तम पाया गया इसके पश्चात केरिओफिलेन, पाईनेने और लिनालूल का 0.1 :0.1:0.2% मिश्रण अच्छा पाया गया। *ट्रा. किलोनिस* द्वारा केरिओफिलेन ऑक्साईड का 0.1% सान्द्रण अत्यधिक परजीवीकरण के लिए प्रभावी पाया गया। कपास के अनुपचारित पौधों की अपेक्षा कपास के पौधों को 24 से 48 घन्टों तक मिथाईल सेलीसिलेट से उद्भासित करके उपचार करने पर अत्यधिक अंडनिक्षेपण पाया गया।

विभिन्न मिश्रणों वाले स्टब्लाईजर्स के साथ ट्राइकोसेन के संग्रहण का अध्ययन दर्शाता है कि शल्क निष्कर्ष के साथ ब्यूटीलेटड हाईड्रोक्सी टौल्यूनी (1:2) का 30 दिनों के संग्रहण करने के पश्चात उपचार करने पर अत्यधिक परजीवीकरण पाया गया।

ट्राइकोग्रामा स्पे. पर अध्ययन

प्रक्षेत्र अनुशंसा के लिए ईमिडिक्लेप्रिड और मोनोक्रोटोफॉस के प्रति सहिष्णु *ट्रा. किलोनिस* विभेद विकसित की गई। *ट्राइकोग्रामा* की अनेक प्रजातियों में से *सीसेमिआ इन्फेरेन्स* के अंडों का *ट्रा. जेपोनिकम* और *ट्रा. ब्रेसीके* द्वारा अत्यधिक परजीवीकरण पाया गया। इनका विकास काल विस्तार 10-13 दिन और सभी प्रजातियों के बीच कोई विशेष अन्तर नहीं पाया गया।

ट्राइकोग्रामा की अनेक प्रजातियों का आई टी एस -2 रिजन श्रेणीगत करके निम्न एक्सेशन संख्याओं, *ट्रा. किलोनिस* (डी क्यू 220703), *ट्रा. ब्रेसीके* (डी क्यू 3114611), *ट्रा. मवन्जाई* (डी क्यू 381279), *ट्रा. इवानेसेन्स* (डी क्यू 381280), *ट्रा. ब्रेसिलीएन्सि* (डी क्यू 381281), *ट्रा. डेन्ड्रोलिमी* (डी क्यू 344045), *ट्रा. एम्ब्रियोफेगम* (डी क्यू 344044), *ट्रा.जेपोनिकम* (डी क्यू 471294) और *ट्रा. प्रेटिओजम* (डी क्यू 381279) के अन्तर्गत जीन बैंक में संग्रहित किया गया। विभिन्न *ट्राइकोग्रामा* जातियों में आई टी एस- 2 क्षेत्र का आकार 1000 बी पी से 500 बी पी तक भिन्न-भिन्न पाया गया। तीन शहरों के आधार पर *ट्रा.आर्मिजेरा*, *ट्रा. एकीए* और *ट्रा. बेक्टरे* के I ग्रुप में आई टी एस- 2 उत्पादों का आकार 700 बी पी से 1000 बी पी तक पाया गया। ग्रुप II में शामिल *ट्रा. जेपोनिकम* और *ट्रा. एम्ब्रियोफेगम* के आई टी एस- 2 उत्पादों का आकार 570 बी पी से 660 बी पी तक और ग्रुप III में शामिल *ट्रा. किलोनिस*, *ट्रा. प्रेटिओजम*, *ट्रा. इवानेसेन्स*, *ट्रा. मवन्जाई*, *ट्रा. ब्रेसिलीएन्सि*, *ट्रा.डेन्ड्रोलिमी* और *ट्रा. ब्रेसीके* के इन सातों आई टी एस- 2 उत्पादों का आकार 500 बी पी से 550 बी पी तक पाया गया। आई टी एस- 2 क्रमों की विभिन्न जातियों को जीन बैंक में संग्रह के लिए रखा गया। आई टी एस- 2 क्रमों का डेन्डोग्राम आधारित तुलना पहले किए गए वर्गीकरण से की गई।

तीनों प्रजातियों के अध्ययन में से केवल *ट्रा. ब्रेसिलीएन्सि* ने ही *वोल्बेकिआ* बेण्ड प्रदर्शित किया जिससे पता चलता है कि *वोल्बेकिआ* इसमें उपस्थित है। दूसरी थेलीटॉकी प्रजाति *ट्रा. एम्ब्रियोफेगम वोल्बेकिआ* नहीं दर्शाती, जिससे यह अनुमान होता है कि इस प्रजाति मे थेलीटॉकी आनुवांशिकी के ऊपर निर्भर करती है।

क्राइसोपर्ला कार्निआ पर अध्ययन

कीट अध्ययन में, नागपुर, पंजाब और दिल्ली की प्रयोगशालाओं से चार विभिन्न कीट संख्याओं को एकत्र, *क्रा. कारनिआ* को एकत्रित करके अलग-अलग रूप से *को. सीफेलोनिका* के अंडों पर तीन पीढ़ीयों तक पाला गया और उनका पी डी बी सी के कीटों से तुलना की गई। इन कीटों की पालने की संख्याओं का विस्तार 85 - 87.4% तक पाया गया। इनके कोकुन भार की दर में नागपुर से लाए गए कीट के कोकुन का भार सर्वाधिक (10 मिग्रा.), इसके बाद दिल्ली (9 मिग्रा.), पंजाब (9 मिग्रा.) और पी डी बी सी से एकत्रित कोकुन

का भार (9 मिग्रा.) पाया गया। सबसे अधिक जीवन काल नागपुर (60 दिन) और दिल्ली (60 दिन) इसके बाद पंजाब (46 दिन) और पी डी बी सी (46 दिन) वाले कीट का पाया गया। नागपुर से एकत्रित *क्रा. कारनिआ* कि जनन क्षमता सबसे अधिक (411 अंडे/मादा), इसके बाद दिल्ली (353 अंडे/मादा), पी डी बी सी (338 अंडे/मादा) और पंजाब (264 अंडे/मादा) से एकत्रित कीट में जननक्षमता पाई गई। विभिन्न क्षेत्रों से एकत्रित *क्रा. कारनिआ* का दीर्घकाल विस्तार 46 से 60 दिनों का पाया गया और नागपुर और दिल्ली से एकत्रित कीट में यह सर्वाधिक, इसके बाद पंजाब और पी डी बी सी से एकत्रित कीट में पाया गया।

मुख विषाक्त, कीटनाशकों जैसे ऐसीफेट (0.67 ग्राम/ली.), मेटासिस्टॉक्स (2 मिली./ली.), केरेटे (0.6 मिली./ली.), सक्सेस (1.2 मिली./ली.) और ईमिडेक्लोप्रिड (0.5 मिली./ली.) की क्षेत्रीय दशाओं में अनुशंसा की गई मात्राओं को अल्ट्रा वॉयलेट से उपचारित अंडों पर छिड़काव करके परीक्षण किया गया। परिणाम दर्शाते हैं कि पंजाब, दिल्ली और पी डी बी सी से एकत्रित किए गए *क्रा. कारनिआ* के लिए परीक्षण किए गए कीटनाशकों में मुख विषाक्तता नहीं पाई गई। ईमिडेक्लोप्रिड (0.5 मिली./ली.) और एसीफेट (0.67 ग्राम/ली.) का प्रयोग नागपुर से एकत्रित *क्रा. कारनिआ* की संख्या के लिए 20% तक घातक सिद्ध होता है। पी डी बी सी, कोयंबटूर, दिल्ली और शिमोगा से एकत्रित *क्रा. कारनिआ* के लिए क्विनलोफॉस 100% घातक पाया गया।

विभिन्न क्षेत्रों से एकत्रित *क्रा. कारनिआ* कीट पर ईस्टीरेज सक्रियता का पैतृक पोलीएक्रीलेमाईड जैल इलैक्ट्रोफोरेसिस में ईस्टिरेज सक्रियता में भिन्नता पाई गई। ईस्टीरेज बेण्ड ई 1- ई 4 चिन्हित किए गए।

क्रा. कारनिआ कीट का आण्विक विशेषता (538 बी पी) बनाई गई और डी एन ए क्रमबद्ध एसेशन संख्या डी क्यू 825504 को नेशनल सेन्टर फॉर बायोटेक्नोलोजी इन्फोर्मेशन, यू एस ए, जीन बैंक में संग्रहित किया गया। *क्रा. कारनिआ* (18-एस आर एन ए) को बेंगलोर से एकत्रित करके उनकी आण्विक विशेषता तैयार की गई।

पादप रोगों का जैविक नियंत्रण

आम के फल की सतह से पृथक यीस्ट संवर्धन आम की तोतापुरी किस्म में, फल सड़न को 27% तक सीमित कर सकता है जबकि अनुपचारित दशा में यह 60% तक पाया गया। दशहरी किस्म में संग्रहण के 12 वें दिन यीस्ट संवर्धन (पृथक्करण 3) आम के फल की हानि को 50% तक सीमित रखता है जबकि जबकि अनुपचारित दशा में यह फल की हानि 93% पाई गई। सफल नियंत्रण की उत्कृष्टता पाने के लिए उपचार की विधियों और पृथक्ककरणों की पहचान के अध्ययन किए जा रहे हैं।

भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली

बेसीलस थ्यूरिन्जिएन्सिस जाति *कुर्सटेकी* पृथक्करणों और उनके मानकों के साथ उन सभी की जैव क्षमता का प्रभाव तितली कूल के कीटों पर आंका गया और *इरियास विटेल्ला* तथा *ल्यूसिनॉडस आर्बोनेलिस* के नवोद्भिदों के प्रति अत्यधिक विषैलापन पाया गया। विशेष आण्विक मार्कर्स के साथ पी सी आर एम्पलिकेशन के आधार पर क्राई 1, क्राई 2, क्राई 3 और क्राई 4 की उपस्थिति में ये पृथक्करण सकारात्मक क्रिया दर्शाते हैं। (भा कृ अनु सं)

गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय

धान की फसल में टॉल्क आधारित नियमन की तुलना में *ट्राइकोडर्मा हरजिआनम* और *स्यूडोमोनाज फ्लूओरेसेन्स* के तेल आधारित नियमनों द्वारा पत्तियों के रोगों का प्रभावी नियंत्रण किया गया और उपज भी अधिक प्राप्त हुई। *रहा. सोलेनाई, स्के. रोल्फसाई, स्केलेरोटिनिआ स्केलेरोटिओरम* और *फ्यूजिओरिअम ऑक्सीपोरम* जाति *पाइसी* के प्रति *ट्रा. हरजिआनम* के प्रभावी विभेदों को पहचाना गया। पी बी ए टी - 16 स्कलेरोशिआ पर तीनों कवक रोगाणुओं पर अपनी कालोनियाँ विकसित करता है। ज्वार के बीजों का उपचार *ट्रा. हरजिआनम*, पी बी ए टी - 39 और पी बी ए टी - 38 द्वारा करते हैं तो यह ज्वार के शीथ ब्लाईट, एन्थ्राक्नॉज और जोनेट लीफ स्पॉट को और जब मिर्च की फसल में बीज/मृदा उपचार किया गया तो एन्थ्राक्नॉज को सफलतापूर्वक नियंत्रित किया जा सका। ग्रीन हाऊस की दशाओं में जब इसका बीज उपचार किया गया तब स्कलेरोशिआ और स्कलेरोशिआ

रहित द्वारा उत्पन्न रोगाणुओं को इन पृथक्करणों द्वारा रोग के ग्रसन को कम किया जा सका।

मटर की फसल में केवल बीजोपचार या विभिन्न जैव नियंत्रण कारकों का पत्तियों के ऊपर छिड़काव साथ मिलाकर करने से पौधों में फफूँदी रोग कम होते हैं और दानों की उपज बढ़ती है।

किसान के खेत में मटर की फसल पर बडे स्तर पर किए गए प्रदर्शन से पता चलता है कि *ट्राइकोडर्मा* के साथ बीजोपचार करने पर बीजों का अंकुरण अधिक और मटर की हरी फलियों की उपज अत्यधिक प्राप्त होती है। आई पी एम आधारित साझा न्यूनतम कार्यक्रम के अन्तर्गत हल्द्वानी (उत्तरांचल) के गोलापार-चोरगलिया क्षेत्र में 81 किसानों के 28.5 एकड क्षेत्रफल पर टमाटर की फसल में पाया कि जैव नियंत्रण कारकों का उपयोग करने पर उपज पर बुरा प्रभाव पडे बिना रसायनिक कीटनाशकों का प्रयोग कम किया जा सका। आई पी एम मोडयूल के अन्तर्गत जैव नियंत्रण कारकों को शामिल करने पर रसायनिक कीटनाशकों की संख्या को कम किया जा सका। आई पी एम विधि अपनाए गए प्लॉटों में लाभःलागत अनुपात अत्यधिक पाया गया।

ट्रा. हरजिआनम और *स्यू. फ्लूओरेसेन्स* के नियमनों का खनिज तेल (डी सी ट्रोन प्लस) में तैयार किया गया। *ट्रा. हरजिआनम* के साथ-साथ *स्यू. फ्लूओरेसेन्स* के नियमनों को 10 महीनों तक संग्रहित करने के बाद भी उनकी सी एफ यू 10^8 प्रति मिली. पाई गई। इन दोनों के संवर्धन में, आम से पृथक किए गए तीनों रोगाणुओं के प्रति *ट्राइकोडर्मा* और *स्यूडोमोनाज* दोनों ही प्रतिरोधी पाए गए। किन्तु कटाई के बाद आम में पैदा होने वाले फल सड़न को रोकने के लिए जब फल डूबोने का उपचार किया गया तब दोनों ही प्रतिरोधी अप्रभावी पाए गए।

ट्राइकोडर्मा हरजिआनम के विभेद पी बी ए टी-43 के स्थानांतरण प्रक्रिया के लिए जीन गन (बायलोजिकल बालिस्टिक) विधि का मानकीकरण किया गया। *ट्राइकोडर्मा हरजिआनम* विभेद पी बी ए टी-43 से हाइग्रोमाइसिन बी प्रतिरोधी प्राप्त किया गया। हाइग्रोमाइसिन प्रतिरोधी का साऊथर्न विश्लेषण दर्शाता है कि क्रमवार स्थानांतरण विभेद प्रतिरोध का जीनोम समनव्यन है।

फसल पीड़कों का जैविक नियंत्रण

गन्ना

(i) *पायरिल्ला*

पंजाब में गन्ने के *पायरिल्ला* कीट का ग्रसन पूरे साल कम ही पाया गया, इसलिए वहाँ पर *एपिरिकेनिआ मिलेनोल्यूका* को पुनः वितरण की आवश्यकता नहीं हुई (पंजाब कृषि विश्वविद्यालय, लुधियाना)। हरियाणा राज्य में, अगस्त - अक्टूबर माह के दौरान *पायरिल्ला* का प्रकोप देखा गया। निम्फ-प्रौढ़ परजीवी कीट *ए. मिलेनोल्यूका* और अंड परजीवी कीटों को, बायोपेस्टिसाईड लेबोरेट्री, क्षेत्रीय अनुसंधान केन्द्र, करनाल और केन्द्रीय जैविक नियंत्रण प्रयोगशालाएँ, जो कि कोपरेटिव शुगर फैक्ट्री, सोनीपत, महाम, शहाबाद और जिन्द में स्थित हैं, में बहुगुणित किए गए। इन परजीवी कीटों को 20,807 एकड़ क्षेत्रफल पर छोड़ा गया जहाँ पर पीड़कों का सफलतापूर्वक नियंत्रण किया गया (चौधरी चरण सिंह हरियाणा कृषि विश्वविद्यालय, हिसार)।

(ii) शल्क

हिसार में किसान द्वारा अपनाई जाने वाली कृषिगत शस्य क्रियाओं और अनुपचारित खेतों की अपेक्षा आई पी एम के अन्तर्गत परभक्षी कीट *काइलोकोरस निग्रीटा* दो बार छोड़ा गया, उन खेतों में गन्ने के शल्क कीटों का ग्रसन और तीव्रता या प्रकोप बहुत कम देखा गया। कटाई के समय यद्यपि सांख्यिकी महत्व में कोई विशेष अंतर नहीं पाया गया (चौ.च सिंह ह कृ वि)।

(iii) बेधक

जै नि प नि, बेंगलोर में *ट्रा. किलोनिस* विभेद की तापक्रम सहिष्णु विभेद का विकास किया गया। चालीस हेक्टेअर क्षेत्रफल पर किए गए प्रदर्शन में तना बेधक को नियंत्रित करने के लिए 50,000 प्रति हेक्टेअर की दर से छोड़ने पर रसायनिक नियंत्रण के समान ही कीट के ग्रसन को 53 से 56 प्रतिशत कम कर देता है। रसायनिक नियंत्रण की अपेक्षा जैविक नियंत्रण (परजीवी कीट छोड़ने) अपनाने पर लागत : लाभ अनुपात कहीं अधिक पाया गया। दो वर्षो के आँकडे दर्शाते हैं कि *ट्रा. किलोनिस* अगोला बेधक के ग्रसन को 63.3 प्रतिशत तक कम कर देता है (पं कृ वि, लुधियाना)।

दो चीनी मिलों के सहयोग से 3,500 एकड क्षेत्रफल पर *ट्रा. किलोनिस* को खेत में छोड़ने का प्रदर्शन किया गया, परिणामस्वरूप अगोला बेधक का 42.3 प्रतिशत की कमी पाई गई। दो वर्षों (2005-06) के आँकडे अगोला बेधक की 48.9% की कमी होना दर्शाते हैं। अप्रैल-जून माह के दौरान *ट्रा. जेपोनिकम* का 50,000 प्रति हेक्टेअर की दर से छः बार छोड़ने पर *स्किरपाफोगा एक्सर्पटेलिस* के नियंत्रण के लिए रसायनिक के समान ही प्रभावी पाया गया और ग्रसन को 51.2 प्रतिशत तक कम किया तथा लागतः लाभ अनुपात अत्यधिक प्राप्त हुआ (पं कृ वि, लुधियाना)।

जोरहट में, *ट्रा. किलोनिस* को खेत में छोड़ने का प्रभाव यह हुआ कि प्लासी बेधक कीट *काइलो ट्यूमिडिकोस्टेलिस* का ग्रसन बहुत कम किया जा सका और अंडे भी अधिक परजीवित प्राप्त हुए। उपचारित खेत से 79.2 टन/हे. उपज प्राप्त हुई जबकि किसान के द्वारा अपनाई गई प्रक्रिया वाले खेत से केवल 58.0 टन/हे. उपज ही प्राप्त हुई (असम कृषि विश्वविद्यालय, जोरहट)।

(iv) सफेद लट

हिसार में, गन्ने के खेत में गोबर की खाद के साथ *ब्यू. बेसिआना* को $6x10^{10}$ कोनिडिआ/कि.ग्रा. की दर से उपचार करने पर सफेद लट का ग्रसन बहुत कम पाया गया। उपरोक्त उपचारित खेतों से एकत्रित सफेद लट अधिकांशतः ग्रसित पाई गई।

(v) वूली माहूँ

असम राज्य में, सितंबर महीने के दौरान गन्ने के वूली माहूँ की संख्या अधिकतम इसके बाद अगस्त और दिसम्बर में पाई गई। दिसम्बर माह के दौरान *डाइफा एफिडिवोरा*, *माइक्रोमस* स्पे. और *सिरफिड* स्पे. तथा दिसंबर माह के दौरान *एनकार्सिआ* अत्यधिक पाई गई। सामान्यतः प्राकृतिक शत्रु कीटों की उपस्थिति के कारण, गन्ने के वूली माहूँ का प्रकोप 2006-07 के दौरान अत्यधिक नहीं पाया गया (अ कृ वि, जोरहट)

महाराष्ट्र राज्य में, 2006-07 के दौरान केवल 6.9% फसल क्षेत्र पर प्रकोप पाया गया। औरंगाबाद क्षेत्र में फसल पर 28.1% प्रकोप पाया गया। यद्यपि पश्चिमी महाराष्ट्र में कीट के प्रकोप की तीव्रता कम पाई गई फिर भी परभक्षी कीटों *माइक्रोमस इगोरोटस* और *डा. एफिडिवोरा* की पर्याप्त सक्रियता पाई गई। (महात्मा फूले कृषि विद्यापीठ, पुणे)

डा. एफिडिवोरा, *माइक्रोमस* और *सिरफिड* की बढ़ती संख्या का अधिकतम और न्यूनतम तापक्रम के साथ महत्वपूर्ण सकारात्मक सहसंबंध पाया गया। असम के गोलाघाट जिले में, *एनकार्सिआ* स्पे. की कीट संख्या और आपेक्षिक आर्द्रता (सुबह के समय) का महत्वपूर्ण सकारात्मक सहसंबंध पाया गया (अ कृ वि, जोरहट)

आन्ध्र प्रदेश राज्य में दो वर्षों के परिणाम देखने पर यह सुझाव दिया गया कि 2005 से 2006 तक दो बार गन्ने के वूली माहूँ का प्रकोप अधिक दिखाई दिया पहली बार जून-अगस्त के दौरान और दूसरी बार नवम्बर-जनवरी माह के दौरान प्रकोप दिखाई पड़ा। राज्य के गन्ना उगाने वाले अनेक दूसरे क्षेत्रों, दक्षिण तेलंगाना क्षेत्र तथा उत्तरी तेलंगाना क्षेत्र में, तटीय इलाकों के जिलों की अपेक्षा प्रकोप अधिक देखा गया। *डा. एफिडिवोरा* मुख्य रूप से परभक्षी कीट पाया गया किन्तु जिन क्षेत्रों में कीटनाशकों का प्रयोग किया गया उन क्षेत्रों में यह परभक्षी कीट नहीं पाया गया। दक्षिण तेलांगाना क्षेत्र में 2005 से 2006 वर्ष के नवम्बर-जनवरी माह के दौरान *डा. एफिडिवोरा* अधिक प्राप्त हुए। वर्ष 2006-07 के दौरान इनकी संख्या नहीं प्राप्त हुई, जो कि इस बात का सूचक है कि पीड़क कीट का ग्रसन नहीं था, साथ ही साथ इस कीट के प्रमुख प्राकृतिक शत्रु कीट *डा. एफिडिवोरा* की संख्या भी कम प्राप्त हुई (आचार्य एन. जी. रंगा कृषि विश्वविद्यालय, हैदराबाद)।

कोयम्बटूर में, वर्ष 2006 में जुलाई - दिसम्बर माह के दौरान प्रायः वूली माहूँ और उसके परभक्षी कीट अधिक सक्रिय पाए गए। सामान्यतः *माइक्रोमस* की सक्रियता कम पाई गई (गन्ना प्रजनन संस्थान, कोयम्बटूर)।

वर्ष 2006 में प्रमुख परभक्षी कीट, *डा. एफिडिवोरा* अक्टूबर और दिसम्बर के दौरान अत्यधिक संख्या में दिखाई दिए। वर्षा और हवा की गति का वूली माहूँ की संख्या के साथ महत्वपूर्ण नकारात्मक सहसंबंध पाया गया (तमिलनाडू कृषि विश्वविद्यालय, कोयम्बटूर)।

का. लेनिजेरा के प्रकोप को न्यूनतम करने के लिए गन्ने की प्रायः बोने वाली विधि (75 से.मी. की दूरी पर) की अपेक्षा चौडी लाईनों की दूरी (45:120 से.मी.) पर बोना उत्कृष्ट सिद्ध हुआ। जनवरी 2007 के अन्तिम सप्ताह के दौरान *का. लेनिजेरा* और *डा. एफिडिवोरा* की अधिकतम संख्या पाई गई। चीनी पुनः प्राप्ति और भार में कमी का विस्तार क्रमशः 9.28 (सी ओ एस 8436) से 18.44 (सी ओ एस 767) तथा 10.54 (सी ओ एस 8436) से 19.75 (सी ओ एस 767) पाया गया (भारतीय गन्ना अनुसंधान संस्थान, लखनऊ)।

आन्ध्र प्रदेश राज्य में, वर्ष 2005- 06 और वर्ष 2006- 07 के आँकडों के परिणाम दर्शाते हैं कि गन्ने के वूली माहूँ के प्रति अनुशंसित शस्य क्रिया के साथ फसल प्रबंधन प्रक्रियायें, किसानों की क्रियाओं से कहीं अधिक अच्छी है (आ एन जी रंगा कृ वि)।

म फु कृ वि, पुणे में बांस और नेट की शैड बनाकर गन्ने के वूली माहूँ के परभक्षी कीट *डा. एफिडिवोरा* का अधिक मात्रा में बहुगुणन उत्पादन किया गया। सात माह की फसल पर अस्थाई नेट शैड से आच्छादित करके केवल दो माह में *डा. एफिडिवोरा* के औसतन 2,540 लारवे/प्यूपों को एकत्र किया गया। ग.प्र.सं., में *डा. एफिडिवोरा* को पालने की बहुगुणन संवर्धन तकनीक प्रयोगशाला में विकसित की गई।

त कृ वि में, जब गन्ने के वूली माहूँ का ग्रसन पत्ती का 90% तक आच्छादित (उपनिवेशन के 40 दिनों के बाद) हो जाता है तब 100 डाइफा /दिन के हिसाब से एकत्र

करते हैं। लारवे उपनिवेशन के 50 -55 दिनों के बाद *डा. एफिडिवोरा* की अधिकतम संख्या एकत्र कर सकते हैं।

महाराष्ट्र में, *डा. एफिडिवोरा* को 1000 लारवे प्रति हेक्टेअर दर से दस बिन्दु क्षेत्रों पर उपनिवेशित करना 60 दिनों के अन्दर ही वूली माहूँ की संख्या को प्रभावपूर्ण ढंग से कम कर देता है (म फु कृ वि)। कोयम्बटूर, पुत्तुर, वेल्लालोरे और इलायामुथुर में क्षेत्रीय मूल्यांकन/प्रदर्शन परीक्षण दर्शाते हैं कि *डा. एफिडिवोरा* को छोडने पर गन्ने के वूली माहूँ की तीव्रता महत्वपूर्ण रूप से कम की जा सकती है (त कृ वि और ग.प्र.सं.)। *डा. एफिडिवोरा* को खेत में छोडने की दर 1000 लारवे प्रति हेक्टेअर निश्चित की गई है (त कृ वि)।

गन्ने के वूली माहूँ का जीवन तालिका अध्ययन दर्शाता है कि गन्ने पर इनकी प्रजनन दर (आर0) 49.6 निम्फ/मादा/पीढ़ी तथा पीढ़ी काल (टी सी) 25.02 दिनों का पाया गया। इनकी संख्या बढ़ने की अंतर्जात क्षमता 0.33 निम्फ प्रति मादा प्रति निम्फ और इनकी संख्या 10.1 गुणा प्रति सप्ताह बढ़ती है। इनके निम्फ और प्रौढ़ संख्या नियत आयु वितरण को क्रमशः 91.4 और 0.02 प्रतिशत योगदान करती है (म फु कृ वि, पुणे)।

आन्ध्र प्रदेश में वर्ष 2006- 07 के दौरान मुख्यतः प्रतिकूल मौसम और पोषक कीटों के उपलब्ध न होने के कारण *एनकार्सिआ फ्लेवोस्कूटेलम* अपने आप को स्थापित नहीं कर पाए (आ एन जी रंगा कृ वि)। कोयम्बटूर में *एनकार्सिआ* छोडने के 11 महीनों के बाद पूर्णतः स्थापित हो गए और इनके प्रौढ़ छोडे गए बिन्दु क्षेत्र की सभी दिशाओं में तीन किमी. तक फैले पाए गए (त कृ वि)।

कपास

कपास की *बी टी* और *बी टी* रहित संकर प्रजातियों में चूषक कीट और परभक्षी कीटों के बीच कोई महत्वपूर्ण अन्तर नहीं पाया गया, क्योंकि पंजाब में पीड़कों की संख्या कम ही थी। अत्यधिक उपज आर सी एच 134 *बी टी* में इसके पश्चात एम आर सी एच 6301 *बी टी* और 651 *बी टी* संकर प्रजाति में पाई गई (पं कृ वि)।

बी आई पी एम पैकेज, *बी टी* कपास प्रयोग करने से परभक्षी कीटों कोक्सीनेलिड्स की संख्या बहुत ज्यादा बढ़ने के साथ -साथ चूषक कीटों का प्रभावी ढंग से सफलतापूर्वक नियंत्रण किया जाता है। वर्तमान समय में प्रयोग की जाने वाली विधियों की अपेक्षा बी आई पी एम पैकेज और *बी टी* कपास के माध्यम से गूलर कम क्षतिग्रस्त और कपास के बीज की उपज अत्यधिक प्राप्त हुई (म फु कृ वि, पुणे)।

आनन्द में, जीवप्रबलित कीट प्रबंधन (बी आई पी एम) के साथ *बी टी* कपास के प्रयोग करने पर कपास के पीडकों को नियंत्रित करने के लिए न्यूनतम लागत

और अत्यधिक लाभ प्राप्त हुआ (आ कृ वि, आनन्द)।

आ एन जी रंगा कृ वि में किए गए जाँच परीक्षण में, किसान द्वारा अपनाई गई प्रक्रिया की तुलना में बी आई पी एम के साथ *बी टी* कपास का प्रयोग करने पर चूषक कीटों की संख्या न्यूनतम मिलती है। बी आई पी एम के साथ *बी टी* कपास उगाने पर *हेलीकोवर्पा आर्मिजेरा* द्वारा क्षति कम जबकि किसान द्वारा अपनाई गई प्रक्रिया के साथ *बी टी* रहित कपास उगाने पर इस कीट द्वारा अत्यधिक क्षति पाई गई। बी आई पी एम के साथ *बी टी* कपास उगाने पर लाभ भी अधिक प्राप्त हुआ।

कोयम्बटूर में, *बी टी*-बी आई पी एम अपनाए गए खेत में चूषक कीट कम पाए गए तथा गूलरों की कम हानि, प्राकृतिक शत्रु कीटों की संख्या अधिक एवं उपज अत्यधिक प्राप्त हुई (त कृ वि)।

प्राकृतिक शत्रु कीटों की संख्या स्थानीय प्रबंधन अपनाए गए प्लॉट में सबसे अधिक, इसके बाद बी आई पी एम अपनाए गए प्लॉट में और कीटनाशक अपनाए गए प्लॉट में बहुत कम पाए गए।

कीटनाशक प्रयोग किए गए प्लॉट से अत्यधिक कपास बीज की उपज प्राप्त हुई जो कि स्थानीय प्रबंधन और बी आई पी एम प्रयोग किए गए प्लॉट की तुलना से काफी अधिक पाई गई। पिछले वर्षों के एकत्र किए गए आँकडे भी इसी प्रकार के रूझान प्रस्तुत करते हैं (पं कृ वि)।

ट्राइकोडर्मा द्वारा बीज उपचार + कपास को *को. ओक्सीडेन्टेलिस* (6:1) के साथ बिखेरना + 10% मक्का और जिनिआ को 10% की दर से रोपण + जैव नियंत्रण का एक प्रयोग करने पर अत्यधिक उपज के साथ अत्यधिक लाभ, अत्यधिक प्राकृतिक शत्रु कीट और पीडक कीटों का अत्यधिक परजीवीकरण के साथ-साथ पीडक कीटों की संख्या और उनके द्वारा होने वाली क्षति कम पाई गई (आ कृ वि, आनन्द)।

चार जोडी लाईनें कपास के साथ-साथ एक-एक लाईन लोबिया और गेंदा + एक जोडी लाईन ज्वार की खेत के किनारों पर बोने से पीड़क कीटों की संख्या कम और प्राकृतिक कीट अधिक सक्रिय दिखाई पडते हैं। उपज भी कुल लाभ के साथ अधिक प्राप्त हुई (आ एन जी रंगा कृ वि)।

मल्लिका *बी टी* में प्राकृतिक शत्रु कीटों की सक्रियता न्यूनतम पाई गई, इसके बाद बन्नी प्रजाति में पाई गई। *बी टी* कपास पारिस्थितिक तन्त्र में प्राकृतिक शत्रु कीट जैसे कोक्सीनेलिड्स, क्राइसोपिड्स, बग्स और मकडियाँ प्रचूर मात्रा में मुख्य रूप से प्राप्त हुई (आ एन जी रंगा कृ वि)।

जै नि प नि, बेंगलोर के सहयोग से कृषि विज्ञान विश्वविद्यालय, धारवाड के रायचूर कैम्पस में कपास की फसल पर *ट्राइकोग्रामेंटिड्स* की दक्षता बढाने के लिए केरोमोन्स की उपयोगिता संबंधी एक क्षेत्रीय परीक्षण दर्शाता है कि पेन्टाकोसेन + ट्राइकोसेन द्वारा उपचारित प्लॉट से गूलर सूँडियों के प्रति *ट्रा. किलोनिस* की दक्षता बढ़ाता है और कपास के बीज की उपज बढ़ाता है।

तम्बाकू

तम्बाकू की फसल क्षेत्र में, *हे. आर्मिजेरा* द्वारा क्षति को नियंत्रित करने के लिए हे. एन पी वी को या गुणवर्धकों के साथ मिलाकर शाम के समय छिड़काव करने पर अत्यन्त प्रभावी पाया गया। तम्बाकू की फसल में *स्पोडोप्टेरा एक्जिगुआ* द्वारा पत्तियों की क्षति को नियंत्रित करने के लिए कीट कवकीय रोगाणु *नो. रिलेई* और *ब्यु. बेसिआना* तथा नीम बीज अर्क को एक समान प्रभावी पाया गया। तम्बाकू की फसल में *हे. आर्मिजेरा* और *स्पो. लिट्यूरा* द्वारा क्षति को नियंत्रित करने के लिए गेंदा और अरण्डी की फसल को प्रपंची फसलों के रूप में प्रभावी पाया गया और इनके प्रयोग करने से प्राकृतिक शत्रु कीटों की संख्या भी अधिक बढ़ी पाई गई (केन्द्रीय तम्बाकू अनुसंधान संस्थान, राजामुन्द्री)।

दलहनी

सोयाबीन की फसल में *स्पो. लिट्यूरा* और पत्ती में जाला बनाने वाली *एपरोरीमा मोडिसेल्ला* कीटों को नियंत्रित करने के लिए किसान द्वारा अपनाई जाने वाली प्रक्रियाओं की अपेक्षा बी आई पी एम विधियाँ अत्यन्त प्रभावी पाई गई (के त अनु सं)। सोयबीन की फसल में बी आई पी एम विधियाँ अपनाने पर 4.6 कु./हे. अतिरिक्त उपज प्राप्त हुई (राष्ट्रीय सोयाबीन अनुसंधान केन्द्र, इन्दौर)।

आ कृ वि, आनन्द में प्रयोगशाला में किए गए विश्लेषणों से पता चलता है कि अरहर की फसल में फली बेधकों को नियंत्रित करने के लिए डी ओ आर-*बी टी* नियमन प्रभावी पाया गया। आ एन जी रंगा कृ वि में प्रयोगशाला अध्ययन में पाया गया कि डी ओ आर-*बी टी* , *हेलीकोवर्पा* के लिए 52.3 प्रतिशत घातक और *मारुका टेस्टुलेलिस* के लिए 63.2 प्रतिशत घातक सिद्ध हुआ। त कृ वि वि में, प्रयोगशाला परीक्षणों में ज्ञात होता है कि *मारुका टेस्टुलेलिस* के लिए डी ओ आर-*बी टी* अत्यन्त सुग्राह्य पाया गया।

अरहर की फसल में, फली बेधकों के प्रति किए गए क्षेत्रीय जाँच परीक्षणों से ज्ञात होता है कि डी ओ आर- *बी टी* को 2 किग्रा./हे. की दर से प्रयोग करने की तुलना में नीम बीज अर्क 5 प्रतिशत और एण्डोसल्फान 0.07 प्रतिशत के समान पाया गया (त कृ वि)। स्लग सूँडी (*लेम्पिडस स्पे.*) को नियंत्रित करने के लिए एण्डोसल्फान 0.07 प्रतिशत की दर से प्रयोग करने पर उत्कृष्ट परिणाम प्राप्त हुए और यही परिणाम डी ओ आर- *बी टी* को 2 किग्रा./हे. की दर से प्रयोग करने पर भी प्राप्त हुए। प्लम मौथ (*एक्सीलेस्टेस एटोमोसा*) को नियंत्रित करने के लिए एण्डोसल्फान 0.07 प्रतिशत और डी ओ आर- *बी टी* को 2 किग्रा./हे. की दर से प्रयोग करने पर एक समान परिणाम प्राप्त हुए (आ कृ वि, आनन्द)।

आँकडे एकत्रित करने पर पाया गया कि एण्डोसल्फान 0.07 प्रतिशत और डी ओ आर-*बी टी* को 2 किग्रा./हे. की दर से प्रयोग करने पर अरहर की फली क्षति में एक समान ही न्यूनतम और दानों की उपज अत्यधिक प्राप्त होती है। एण्डोसल्फान 0.07 प्रतिशत की दर से प्रयोग करने पर अधिकतम लाभ , इसके बाद 5% नीम बीज अर्क प्रयोग करने पर लाभ प्राप्त होता है (आ कृ वि, आनन्द)।

धान

केरल (के कृ वि), पंजाब (पं कृ वि) और जोरहट (अ कृ वि) में किए गए जाँच परीक्षणों से ज्ञात होता है कि धान के तना बेधक और पत्ती मोडक कीटों के लारवों को नियंत्रित करने के लिए डी ओ आर-*बी टी* बहुत प्रभावी है और यह रसायनिक नियंत्रण के समान प्रभावी पाई गई। *बी टी* उपचारित क्षेत्रों से धान के दानों की अत्यधिक उपज, इसके बाद रसायनिक नियंत्रण द्वारा उपज प्राप्त हुई।

जैविक धान और बासमती धान रोपण के 30 दिनों के बाद से *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* प्रत्येक को 1,00,000 प्रति हेक्टेअर की दर से छोड़ने पर प्रभावी पाया गया। तीन वर्षों (2004-2006) के एकत्र आँकडों का विश्लेषण करने पर पाया गया कि जैविक खेती में पीडक नियंत्रण और अनुशंसित प्रक्रियायें एक समान पाई गई। धान के पत्ती मोडक कीट और तना बेधक कीटों को नियंत्रित करने के लिए बडे स्तर (10 हेक्टेअर क्षेत्रफल पर) पर किए गए प्रदर्शन में आई पी एम (कार्टेप हाईड्रोक्लोराईड का एक प्रयोग, 25 किग्रा./हे. और *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* प्रत्येक को 1,00,000 प्रति हेक्टेअर की दर से एक सप्ताह के अन्दर सात बार छोडना) और रसायनिक नियंत्रण (रोपण के 30, 50 और 70 दिनों के बाद कार्टेप हाईड्रोक्लोराईड 25 किग्रा./हे. की दर पर प्रयोग) एक समान प्रभावी साबित हुए। तीन वर्षों (2004-06) के एकत्रित आँकडे दर्शाते हैं कि बी आई पी एम अपनाने पर पत्ती मोडक कीट और तना बेधक कीटों का ग्रसन तथा दानों की उपज, रसायनिक नियंत्रण के समान पाई गई (पं कृ वि)।

वर्ष 2005-2007 के दौरान चार मौसमों में एक ही क्षेत्र में धान के जैविक उत्पादन के लिए बी आई पी एम विधियों से पता चलता है कि जैविक खेती अपनाए गए खेत में परभक्षी कीटों की संख्या महत्वपूर्ण रूप से अधिक व उपज रूढ़िगत रूप से उगाने वाले धान के समान पाई गई (के कृ वि)।

किसान द्वार अपनाई गई विधियों की अपेक्षा बी आई पी एम द्वारा दानों की उपज अत्यधिक पाई गई। मृदा विश्लेषण करने पर पता चलता है कि किसान द्वारा अपनाई गई प्रक्रिया वाले परीक्षण में जैविक कार्बन की मात्रा 0.35% इसकी तुलना में जैव प्रबलित परीक्षणों की मृदा में 0.37% उपलब्ध पाई गई (राष्ट्रीय समेकित नाशीजीव प्रबंध अनुसंधान केन्द्र, नई दिल्ली)।

जोरहट में, जैविक पैकेज प्रयोग करने पर पीडकों की संख्या और फसल क्षति में काफी कमी तथा उपज और लागतःलाभ अनुपात अत्यधिक प्राप्त हुआ (अ कृ वि, जोरहट)।

त्रिसुर जिले के आदत पंचायत में धान के 3000 एकड क्षेत्रफल पर, बी आई पी एम अपनाया गया और *ट्राइकोग्रामा* स्पे. की एक लाख/ हेक्टेअर की दर से प्रयोग करने की अनुशंसा की गई (केरल कृषि विश्वविद्यालय, त्रिसुर)।

तिलहन

सरसों में, रसायनिक नियंत्रित प्लॉटों में और डी ओ आर-*बी टी* द्वारा उपचारित प्लॉटों में सा फ्लाई कीट द्वारा क्षति में कोई विशेष अन्तर नहीं पाया गया। यद्यपि, व्यवसायिक *बी टी* 2.0 किग्रा. और रसायनिक नियंत्रण के समान पाया गया (अ कृ वि, जोरहट)।

नारियल

हिर्सुटेल्ला थोम्पसोनाई का तीन गुणवर्धन करने वाले मिश्रण जैसे ग्लिसरोल, यीस्ट अर्क पाउडर और माल्ट अर्क ब्रोथ (एम ई बी) के साथ मिश्रित करके प्रयोग करने पर नारियल की नुसि (माईट) की संख्या को काफी कम कर देता है। उपचारित प्रतिदर्श के दौरान सिद्ध होता है कि सभी छिड़काव किए गए वृक्षों पर यह कवक, नुसि (माईट) में रोग पैदा करने में सक्षम होता है। कवक को एम ई बी के साथ मिलाकर प्रयोग करने पर नारियल की माईट के ग्रसन को 97.2% तक कम कर देता है (जै नि प नि, बेंगलोर)।

के. बा. फ. अनु. सं. के प्रक्षेत्र, कासरगोड पर *हि. थोम्पसोनाई* के द्वारा उपचार या प्रयोग काल के उपचारों के बीच कोई विशेष अन्तर नहीं पाया गया (केन्द्रीय बागानी फसल अनुसंधान संस्थान, कासरगौड)। के कृ वि में किए गए परीक्षणों से विदित होता है कि *हि. थोम्पसोनाई* डाइकोफोल के द्वारा उपचार करने पर नारियल की माइट की संख्या को एक समान रूप से ही कम करते हैं (के कृ वि)।

ब्रेकोन स्पे. को विभिन्न प्रान्तों से एकत्र करके उनकी तुलना की गई। इनमें से जीवन, परजीवीकरण और प्रजननकाल क्षमता के आधार पर कासरगोड (केरल) और पिटाप्पाल (उडीसा) से एकत्रित *ब्रेकान* उत्कृष्ट पाए गए। तिरूवंतपुरम और उडीसा से एकत्र संवर्धनों में मादा कीट द्वारा अंडनिक्षेपण काल अधिकतम पाया गया (के. बा. फ. अनु. सं.)।

नारियल की पत्ती की काले सिर वाली सूँडी के प्रति *ट्रा. एम्ब्रियोफेगम*, *गो. निफेन्टिडिस* और *का. एक्जिगुअस* को दो मौसमों तक छोडा गया, परिणाम दर्शाते हैं कि जैव-नियंत्रण कारकों को छोडने के पश्चात पीड़क कीट की संख्या बहुत कम हो गई (के कृ वि)।

ओरीक्टस बेक्यूलो वायरस + *मे. एनाईसोप्लिए* + फेरोमोन प्रपंच का मिश्रित प्रयोग, विषाणु उपचार की अपेक्षा सफल नियंत्रण नहीं कर पाया (के. बा. फ. अनु. सं.)।

गोबर के खाद के गड्ढों में रहाईनोसेरस ग्रब्जों का प्रबंधन करने के लिए *मे. एनाईसोप्लिए* जाति मेजर कवक का प्रयोग किया गया, परिणाम स्वरूप उपचारित माध्यम में 100% ग्रब्ज मृत पाईं गईं (के कृ वि)।

ऊष्ण कटिवन्धीय फल फसलें

पोमेलो की फसल में, *ब्यू. थ्युरिन्जिएन्सिस* का 1 मि.ली./ली. की दर से सप्ताहिक अन्तराल पर प्रयोग करने से *फाइलोक्निस्टिक सिट्रेल्ला* की संख्या को काफी कम किया गया। चीकू की फसल में, *कोकस विरिडिस* की संख्या को *एफेलिनिड* परजीवी कीट, *कोकोफेगस* स्पे. नियंत्रित करने में सफल रहा (भा बा अनु सं)।

शरीफा की बेमौसम फसल में, *क्रिप्टोलीमस मोन्ट्रयूजिएरी* को छोडने पर यह *प्लेनोकोकस सीट्राई*, *फेरिसिआ विरगेटा* और *मेकोनेलिकोकस हिर्सुटस* मीलीबगों के ग्रसन को काफी कम कर देता है। परभक्षी कीट, *क्रि. मोन्ट्रयूजिएरी* के लिए सुरक्षित कीटनाशकों की जाँच में नए-नए रसायनों पर परीक्षणों में ईमिडेक्लोप्रिड 0.5 मिली./ली., फ्लूवेलीनेट 0.5 मिली./ली., प्रोफेनोफोस 1 मिली./ली. और फ्लूफेनोक्सूरोन 1 मिली./ली. को परभक्षी कीट के लिए सुरक्षित मात्रा पाई गई। विषाक्त अवशेष अध्ययन में पाया गया कि प्रौढ बीटल्स के लिए प्रोफेनोफोस + साईपरमेथ्रिन का प्रयोग के 7 दिनों के बाद हानिकारक नहीं है जबकि बाईफेन्थ्रिन प्रयोग के 14 दिनों बाद हानिकारक नहीं होता है। गमले में लगे अमरूद के पौधों में *एनकार्सिआ गोडेलोऊपे* के बहुगुणन विधि को ग्लास हाऊस की दशाओं में मानकीकरण किया गया, जिसमें संवर्धन पूरे वर्ष उपलब्ध रहा (भा बा अनु सं)।

महाराष्ट्र में शोलापुर के नजदीक तुलजापुर क्षेत्र में अंगुर की फसल में, गुलाबी मीलीबग, *मेकोनेलिकोकस*

हिर्सुटस के प्रति *क्रि. मोन्ट्रयूजिएरी* के 5,000 लारवे/हे. की दर से छोडने के प्रदर्शन में एक वर्ष के अन्दर ही मीलीबगों के ग्रसन को 70.5 प्रतिशत से घटाकर 0.75 प्रतिशत तक कर देता है (भा बा अनु सं/ राष्ट्रीय अंगूर अनुसंधान केन्द्र, पुणे)।

शीतोष्ण फल फसलें

बाग में आई पी एम के अन्तर्गत मार्च से सितम्बर माह में *एनकार्सिआ पर्निसिओसी* को 1000 कीट/वृक्ष की दर से सात बार (मई से जुलाई) छोडने के परिणामस्वरूप सेन जोस शल्क कीटों का औसत परजीवीकरण 7 से 25 प्रतिशत तक पाया गया। अप्रबंधित बागों में भी *ए. पर्निसीओसी* और *एफाइटिस प्रोक्लिआ* द्वारा कीटों का प्राकृतिक परजीवीकरण दर्ज किया गया जो कि उसी निरीक्षण के दौरान 6.02 से 18.51 प्रतिशत तक बढ़ता है। यद्यपि किसानों के बागों में परजीवीकरण स्तर बहुत कम पाया गया (शेरे-कश्मीर कृषि विज्ञान और प्रौद्योगिकी विश्वविद्यालय, श्रीनगर)।

हेटेरोरहाब्डिटिस बेक्टेरिओफोरा (2.83 लाख संक्रमित ज्यूवेनाईल्स/वृक्ष) और *स्टेईनर्नेमा फेल्टिए* (2.9 लाख संक्रमित ज्यूवेनाईल्स/वृक्ष) की दर पर छोडने पर सेब के वूली माहूँ के मूलोद्गम को नियंत्रित करने में असफल रहा। जब *स्टे. फेल्टिए* को 200 संक्रमित ज्यूवेनाईल्स/वृक्ष की दर से छोडा गया तो अनुपचारित की अपेक्षा इनमें माहूँ की कालोनी कम पाई गई, उनका आकार और फैलाव कम पाया गया। प्रयोगशाला में किए गए परीक्षणों में पाया गया कि सेब का जड़ बेधक, *डोरीस्थेनीस ह्यूज्लाई* की प्रथम निरूपीय ग्रब के प्रति *स्टे. फेल्टिए* का $2x10^5$ संक्रमित ज्यूवेनाईल्स/वर्ग मीटर संवेदनशील पाया गया। सर्दी के मौसम में, पेट्री प्लेट में भीगी स्पाँज के ऊपर रखी *टेट्रानिकस टेलारीअस*, माईट से संक्रमित गुलाब की पत्ती पर परभक्षी माईट, *एम्बलाईसिअस लोन्गिस्पाईनोसस* को गुणित किया जा सका। *टे. टेलारीअस* और ग्रीन हाऊस में सफेद मक्खी के निम्फ *ट्राइएल्यूरोडस वेपोरिओरम* पर एक परभक्षी माईट, *एम्बलाईसिअस (यूसिअस) डेल्हिएन्सिस* को भक्षण करते देखा गया तथा एक अन्यपरभक्षी कीट माईट *ए. इन्डिरे* को आम की पत्तियों पर आम के फूदकों का भक्षण करते पाया गया (डॉ.यशवन्त सिंह परमार उद्यान और वानिकी विश्वविद्यालय, सोलन)।

प्रयोगशालाओं की दशाओं में, जब अनेक सूक्ष्म जीवी कीटनाशकों जैसे *व. लेकेनाई* , *हि. थोम्पसोनाई*, *ब्यू. बेसिआना* और *मे. एनाईसोप्लिए* प्रत्येक को $1x10^9$ बीजाणु/मिली. की सान्द्रता में 5 ग्राम/ली. की दर पर जब यूरोपियन लाल माईट, *पेनोनाईकस उल्माई* के प्रति मूल्यांकन किया गया तो पाया गया कि *व. लेकेनाई* और *हि. थोम्पसोनाई* द्वारा घातकता प्रतिशत अत्यधिक , इसके पश्चात *मे. एनाईसोप्लिए* और *ब्यू. बेसिआना* द्वारा घातकता पाई गई (शे क कृ वि और प्रौ वि)।

सब्जी फसलें

भिंडी की फसल में, *इरियास* स्पे. के प्रबंधन के लिए डी ओ आर *बी टी* की 2 किग्रा./हे. की दर से प्रयोग करना रसायनिक नियंत्रण के समान पाया गया। *ल्यू. ओर्बोनेलिस* के प्रबंधन के लिए रसायनिक नियंत्रण और डी ओ आर-*बी टी* की 2 किग्रा./हे. की दर से प्रयोग करना रसायनिक नियंत्रण के समान पाया गया। ई पी एन का 2 बिलियन/हे. की दर से प्रयोग करने पर पीडक कीटों का औसत दर्जे का नियंत्रण देखा गया (पं कृ वि)।

दो मौसमों में परीक्षण किए गए और पाया गया कि डी ओ आर-*बी टी* की 2 किग्रा./हे. की दर से उपचारित प्लॉट में फलों की अत्यधिक उपज और बैंगन फलबेधकों का ग्रसन न्यूनतम पाया गया (के कृ वि)।

एस डी ए यू द्वारा किए गए परीक्षणों से पता चलता है कि अनोपचारित प्लॉट की अपेक्षा आई पी एम अपनाए गए प्लॉटों में पात गोभी की क्षतिग्रस्तता प्रतिशत और उपज के आधार पर उत्कृष्ट पाया गया। यद्यपि आई पी एम प्लॉट की अपेक्षा रसायनिक नियंत्रण प्लॉट उत्कृष्ट पाए गए।

पातगोभी की डायमंड ब्लैक मौथ को नियंत्रित करने के लिए डी ओ आर-*बी टी* और हाल्ट की सभी मात्राएँ रसायनिक नियंत्रण के समान पाई गई (पं कृ वि)।

अनुपचारित की तुलना में जब पात गोभी का शीर्ष बनना प्रारम्भ होता है उस समय से साप्ताहिक अन्तराल पर जैविक नियंत्रण कारकों (डी ओ आर-*बी टी* 1 ग्राम/ली., *मे. एनाईसोप्लिए* $1x10^9$ बीजाणु/मिली., *ब्यू. बेसिआना* 15 ग्राम/ली. और *स्टे. कार्पोकेप्से* 1 बिलियन/हे. की दर से) का छिड़काव करते हैं, इस प्रकार कुल

5 छिड़काव करने के परिणामस्वरूप डायमंड ब्लैक मौथ के लारवों की संख्या महत्वपूर्ण रूप से कम की जा सकी। अनुपचारित की तुलना में *बी टी* 1 ग्राम / ली. की दर से हफ्ते के अन्तराल पर अ साप्ताहिक 6 बार अंड परजीवी कीट, *ट्रा. ब्रेसिके* को 40-60 हजार प्रौढ़ /सप्ताह की दर से अर्थात 3,00,000 प्रौढ़ /हे. की दर से छोडने पर पात गोभी में डायमंड ब्लैक मौथ की संख्या महत्वपूर्ण रूप से कम हुई और बाजार योग्य उपज भी बढ़ी पाई गई (भा बा अनु सं)।

पात गोभी में एन्डोसल्फान से उपचारित प्लॉट से उपज और लाभ:लागत अनुपात अत्यधिक प्राप्त हुआ इसके बाद डी ओ आर *बी टी* उपचारित प्लॉटों से प्राप्त हुआ। एंडोसल्फान उपचारित प्लॉट की तुलना में *बी टी* उपचारित और अनुपचारित प्लॉटों में लारवों का परजीवीकरण अत्यधिक प्राप्त हुआ। स्पिनोसेड उपचार और डी ओ आर-*बी टी* का 1 किग्रा./हे की दर से प्रयोग करने पर पातगोभी की उपज और लाभ:लागत अनुपात अत्यधिक पाया गया जो कि *ट्रा. ब्रेसीके* के प्रयोग करने से उत्कृष्ट पाया गया (एम पी यु ए टी)।

लारवे दिखाई देने पर डी ओ आर-*बी टी* का 1 ग्रा./ली., *मेटारहाईजियम एनाईसोप्लिए* $1x10^9$ बीजाणु/ मिली. और *स्टेईनर्नेमा* को 1 बिलियन/हे. की दर से साप्ताहिक अन्तराल पर प्रयोग करने के परिणाम स्वरूप गर्किन्स फसल के *डायाफेनिआ इन्डिका* के लारवों की संख्या को महत्वपूर्ण रूप से कम किया जा सका। अनुपचारित की अपेक्षा सभी उपचारों के प्रयोग करने के परिणाम स्वरूप कटाई के समय फलों की क्षति प्रतिशतता महत्वपूर्ण ढंग से कम पाई गई (भा बा अनु सं)।

थ्रिप्स टेबेसी को बहुतायात में पालने के लिए दो पोषक पौधों (सेम की फली और प्याज की शीथ) में से पोषक पदार्थ के लिए प्याज की शीथ को अनुकूल पाया गया। एन्थोकोरिड, *ओरिअस टेन्टेलिस* का प्रौढ़ *स्किरटोथ्रिप्स डोर्सेलिस* के दूसरे निरूप के 6-25 लारवे (माध्य 13.1) प्रतिदिन खाता है और 7-22 दिनों तक जीवित रहता है (भा बा अनु सं)।

कोल फसल में *बेसीलस थ्युरिन्जिएन्सिस* उपप्रजाति *कुर्सटेकी* को 1 किग्रा./हे. और ईको नीम प्लस को 2 मिली./ली. की दर से प्रयोग करने पर *पिएरिस ब्रेसीके* के नवजात प्रथम निरूप के लारवों को नियंत्रित करने के लिएप्रभावी पाया गया। प्रयोगशाला में किए गए परीक्षण में पाया गया कि आईसक्रीम कप में जिसमें प्रत्येक कप में *बे. कोरीसिआ* की दूसरे निरूप की एक ग्रब होती है उसमें *ब्यूवेरिआ ब्रोन्गिनिआर्टी* (स्थानीय विभेद) को 10^{14} कोनिडीआ/हे. की दर से प्रयोग करने पर उपचार करने के चार सप्ताहों के बाद 70 प्रतिशत तक घातक पाया गया और शेष ग्रबों के 60% ग्रब मायकोसिस के कारण मरे पाए गए। सरकारी आलू प्रक्षेत्र, सिलारू (शिमला जिला) में सफेद लट, *ब्राह्मीणा कोरीएसीआ* के नियंत्रण के लिए क्षेत्रीय परीक्षण में *ब्यू. ब्रोन्गिनिआर्टी* द्वारा उपचारित (10^{14} कोनिडीआ/हे.)

प्लॉट में सफेद लट की संख्या न्यूनतम (2.2/मी. लाईन) पाई गई (डा.य सि प उ और वा वि)।

खरपतवार का जैविक नियंत्रण

केरल और तमिलनाडू से *साईप्रस रोटून्डस* का कोई भी प्राकृतिक शत्रु कीट नहीं प्राप्त हुआ। लुधियाना में खेत से एकत्र *सा. रोटून्डस* के नमुनों में जुलाई के दूसरे हफ्ते के दौरान 2% कवकीय संक्रमण और अक्टूबर माह के दौरान 1 से 3% संक्रमण पाया गया। वर्ष 2006 के दौरान असम के जोरहट, गोलाघाट और नवगाँव जिलों से *सा. रोटून्डस* पर तितली कूल का एक बेधक कीट प्राकृतिक शत्रु कीट के रूप में पाया जा सका।

सफेद लट का जैविक नियंत्रण

गो ब पं कृ एवं प्रौ वि के रानीचौरी केन्द्र की प्रयोगशाला दशाओं में *होलोट्रिकिआ लोन्गिपेनिस* के तीसरे निरूपीय ग्रब के प्रति ई पी एन के स्थानीय विभेद *स्टेईनर्नेमा ग्लासेरी* का जैव दक्षता अध्ययन किया गया। निवेशन की अत्यधिक मात्रा 1500 संक्रमित ज्यूवेनाईल्स/ग्रब प्रयोग करने के 7 वें दिन से कुल मिलाकर 90% तक घातक पाई गई।

पोलीहाऊस फसलों के पीड़कों का जैविक नियंत्रण

पोलीहाऊस में जरबेरा के पौधों पर कवकीय नियमनों जैसे *व. लेकेनाई*, *हि. थोम्पसोनाई* , *में. एनाईसोप्लिए* और *ब्यू. बेसीआना* द्वारा थ्रिप्स

(*फ्रैन्कलिनिएल्ला* स्पे.) को कम करने के लिए रसायनिक नियंत्रण के समान ही पाया गया (के कृ वि)।

पोलीहाऊस में खीरे की फसल में, ग्रीनहाऊस सफेद मक्खी के ग्रसन का प्रबंध करने के लिए ईमिडेक्लोप्रिड 0.00925% और *पेसीलोमाईसेस फ्यूमोसोरोसिअस* का 10^{11} कोनिडीआ/मिली. पानी का प्रयोग उपचार के 15 दिनों के अन्दर एक समान प्रभावी सिद्ध हुआ (डा.य सि प उ और वा वि)।

पोलीहाऊस में मिर्च की फसल में, थ्रिप्सों के प्रति *मे. एनाईसोप्लिए* अत्यंत प्रभावी पाया गया (म फु कृ वि, पुणे)।

जरबेरा में सफेद मक्खी के नियंत्रण के लिए *व. लेकेनाई* के छिड़काव का मूल्यांकन किया गया और पाया कि यह छिड़काव एक सप्ताह के लिए प्रभावी होता है इसके बाद इनकी संख्या बढ़ती है (रा स ना प्र अनु के)।

बहोत्पादन इकाईयों की स्थापना

-के कृ वि में *ब्यू. बेसीआना*, *मे. एनाईसोप्लिए* और *व. लेकेनाई* का उत्पादन करने के लिए एक रोग विज्ञान प्रयोगशाला की स्थापना की गई। यह प्रयोगशाला विद्यार्थियों, किसानों और प्रसार एवं विस्तार कार्यकर्ताओं को शिक्षण एवं प्रशिक्षण कार्यों में सहायता करती है।

रहाईनोसेरस बीटल का क्षेत्रीय स्तर पर नियंत्रण करने के प्रदर्शनों के लिए *मे. एनाईसोप्लिए* प्रजाति मेजर का बहुत संख्या में उत्पादन किया गया।

नारियल कीट, *ओ. एरेनोसेल्ला* को नियंत्रित करने के लिए, त कृ वि द्वारा परजीवी कीट, *ब्रेकोन हेबेटर* का बहुत बडे पैमाने पर उत्पादन और खेप भेजने का कार्य किया गया। इरोड जिले के संयुक्त निदेशक, कृषि विभाग को 2.88 मिलियन परजीवी कीट भेजे गए, जिन्हें इरोड जिले के अरचलूर, मोडाकुरचि खण्ड में छोड़ा गया जहाँ पर 96,040 वृक्षों को जैविक नियंत्रण के अन्तर्गत लाभानिवत किया गया।

हरियाणा में कोपरेटिव शुगर फैक्ट्री से जुडी हुई जैव-नियंत्रण प्रयोगशालाओं में जाँच परीक्षण करने के उद्देश्य से *ए. मीलेनोल्यूका* के 23,572 अंड समूह और 32,774 कोकून, *पा. पर्पुसिल्ला* कीट के अंड परजीवी कीट के 13,778 अंड समूह, *ट्रा. किलानिस* के 30,82,54,000 परजीवित अंडे और *ट्रा. जेपोनिकम* के 2,08,04,000 परजीवित अंडे तथा *ब्यू. बेसीआना* तथा *ब्यू. ब्रोन्गिनिआर्टी* का बहोत्पादन किया गया (चौ च सि ह कृ वि)।

म फु कृ वि, पुणे में, चार पोषक कीटों, छः परजीवी कीटों, तीन परभक्षी कीटों और दो एन पी वी निरंतर पाले गए। अनुसंधान इकाईयों और किसानों को उनकी आवश्यकताओं के अनुसार जैव कारकों की खेप भेजी गई।

प्रौद्योगिकी स्थानान्तरण

ऐमोरुस प्रतिरोधी कवक टॉल्क आधारित नियमन के उत्पादन के लिए एक साधारण विधि बनाकर प्रौद्योगिकी विकसित करके निजी कम्पनियों को बेचा गया। तम्बाकू में *स्पोडोप्टेरा लिट्यूरा* और *हेलीकोवर्पा आर्मिजेरा* के नियंत्रण के लिए प्रपंची फसल के रूप में क्रमशः गेंदा और अरण्ड फसलों का विश्लेषण करके सन् 2005-07 में किसान के खेतों में सफल प्रयोग किया गया। *स्यूडोमोनाज फ्लूओरेसेन्स* का गोबर की खाद में बहुगुणन करने की विधि का विकास किया गया और इस विधि को पैटेन्ट करने के लिए उचित माध्यम को भेजा गया है। त्रिसूर जिले के आदत पंचायत के 3000 एकड़ क्षेत्रफल पर धान के पत्ती मोड़क कीट और तना बेधक कीटों का नियंत्रण करने के लिए *ट्राइकोग्रामा* स्पे. को एक लाख/हे. की दर से सफल प्रयोग करने के बाद बी आई पी एम का आदर्श पैकेज तैयार किया गया। इस सफल प्रौद्योगिकी पर 2006-07 में एक विडियो वृत्तचित्र तैयार किया गया।

मानव संसाधन विकास

जै नि प नि, बेंगलोर के दस वैज्ञानिकों ने, परियोजना नियमन और मूल्यांकन, प्राकृतिक शत्रु कीटों का आण्विक विश्लेषण और केल्सिड परजीवी कीटों का जैव वर्गीकरण पर विभिन्न प्रशिक्षण कार्यक्रम किए। आस्ट्रेलियन नेशनल इन्सेक्ट (ए एन आई सी), सी एस आई आर ओ कीट विज्ञान, केनबरा, आस्ट्रेलिया से कोक्सीनेलिड एकत्रीकरण का अध्ययन विशेषरूप से आस्ट्रेलेशियन और ओरिएन्टल/भारतीय जीव-जन्तुओं पर यह अध्ययन किया गया। तीन वैज्ञानिकों ने विदेशों में आयोजित अंतर्राष्ट्रीय कार्यशालाओं में भाग लिया। वर्ष 2006-07 के दौरान जैविक नियंत्रण परियोजना

निदेशालय ने जैविक नियंत्रण के विभिन्न पहलुओं पर 20 प्रशिक्षण कार्यक्रम आयोजित किए, जिनमें भारतीय कृषि अनुसंधान परिषद के विभिन्न संस्थानों, राज्य कृषि विश्व विद्यालयों, राज्यों के कृषि और बागवानी विभागों तथा व्यवसायिक उत्पादन इकाईयों के 79 वैज्ञानिकों ने भाग लिया।

राजस्व प्राप्ति

परामर्श देने, तकनीकी बुलेटिनों और प्राकृतिक शत्रु कीटों के क्रय करने से परियोजना निदेशालय ने 13.81 लाख रूपयों का राजस्व प्राप्त किया।

प्रकाशन

वैज्ञानिक जरनल्स में अड़सठ शोध-पत्र प्रकाशित हुए। विभिन्न सिम्पोजिअम/संगोष्ठियों/कार्यशालाओं में साठ शोध-पत्र प्रस्तुत किए गए। बारह पुस्तक अध्याय/वैज्ञानिक समीक्षाएँ लिखी गई और बाईस पोपुलर लेख/तकनीकी तथा प्रसार बुलेटिन प्रकाशित किए गए।

3. EXECUTIVE SUMMARY

An extensive research programme in basic and applied research was undertaken at the Project Directorate of Biological Control (PDBC) as well as 10 State Agricultural Universities (SAUs) and six Indian Council of Agricultural Research (ICAR)-based centres besides some voluntary centres under All-India Co-ordinated Research Project (AICRP) on Biological Control during 2006-07 to develop biocontrol-based technologies for the eco-friendly management of key pests, diseases of crops and weeds. Emerging problems like eco-friendly management of sucking pests on *Bt* cotton, the sugarcane woolly aphid 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 2006-07 have been carried out successfully and the results are summarized hereunder.

Basic research

Project Directorate of Biological Control, Bangalore

Biosystematics

A new sibling species of *Halyzia straminea* was described from India and Nepal. Taxonomic revisions of *Synona*, *Scymnodes*, *Apolinus*, *Rhynchortalia*, and *Cryptolaemus* (in part) were carried out. A new species of *Horniolus* was recorded from Karnataka. Twenty-five new photographs were added to our website on Indian coccinellids. Three new fact sheets were added to the compendium of fact sheets on common coccinellids.

Coccinellid collections at the Australian National Insect Collection (ANIC), CSIRO Entomology, Canberra, Australia, were studied, with particular emphasis on the Australasian and Oriental/ Indian fauna.

Biosystematics studies have been initiated on *Trichogramma* and *Trichogrammatoidea*. *Trichogramma flandersi* and *Trichogramma chilonis* were collected on *Chilo infuscatellus*, *Trichogramma japonicum* on *Scirpophaga incertulas*, *Trichogramma hesperidis* on Hesperiidae on rice, and *Trichogrammatoidea armigera* on *Helicoverpa armigera* on pigeonpea, *T. chilonis* on *Lampides boectius* on field bean, and all these cultures are maintained on eggs of *Corcyra cephalonica*. A species of *Trichogramma* was collected on eggs of Sphingidae and another species on the eggs of a bruchid.

Introduction of natural enemies

One import permit for the import of *Heteropsylla spinulosa* for the biological control of *Mimosa diplotricha* was obtained in March 2007. Applied for imports of *Trichogramma seamblidis*, *T. pretiosum*, *T. evanescens*, *T. embryophagum* and *T. cacoeciae*.

The stem gall fly of *Chromolaena odorata*, released during July 2005, had established in fields at two locations and has successfully overcome the critical periods of two winter and summer seasons. The gall fly density was higher at Tataguni village than at GKVK. The gall fly had spread to a distance of 1 km at GKVK and 2 km at Tataguni village during last year.

Parasitoids and predators

The observations on the morphological changes that occur in aphids parasitised by *Encarsia flavoscutellum* showed that a dark patch with less woolly covering near the caudal end probably indicated that the aphid was parasitised and from 70% of such suspected aphids the parasitoids emerged.

DNA was extracted from *Dipha aphidivora*, *Micromus igorotus*, *E. flavoscutellum* and *Ceratovacuna lanigera* to enable identification of the ITS-1 region from each of them. Only *E. flavoscutellum*, which had about 700 bp could be identified.

Campoletis chlorideae cocoons could be obtained from *H. armigera* larvae infesting chickpea during the months of December 2006 and February 2007 in and around Bangalore and during December from cotton ecosystem in Coimbatore. *Orius tantillus* could be collected from maize (March-October 2006), marigold (December 2006), sunflower (January 2007) and rose (February-March 2007). *Orius maxidentex* could be collected from sunflower (January 2007) and rose (February-March 2007) from Bangalore and it was also collected from sunflower crop in Pune. *Blaptostethus pallescens* could be collected from maize during September-October 2006 and from grapes and rose during February-March 2007.

After two releases of *C. chlorideae*, number of larvae per plant was 0.95 in treatment and 1.35 in control, while 0.1% of the larvae collected from the control plot were parasitised and 22.2% in treated plot. At the end of four releases, the pod damage in chickpea was 28.7% in control and 3.2% in treatment.

Sitotroga cerealella eggs proved to be more suitable for rearing *O. tantillus* based on the higher reproductive rate. The net reproductive rate of *O. tantillus* was higher at 24, 28 and 32°C in comparison to 20°C. Hypothetical F2 females was highest at 28°C and at this temperatures reproductive rate, intrinsic rate of increase and weekly multiplication rate were also reasonably high, indicating the suitability of this temperature for rearing *O. tantillus*.

The warehouse pirate bug, *Xylocoris flavipes*, could be successfully multiplied on *Corcyra cephalonica* eggs. One nymph could feed on a mean of 3.4 eggs/day and the adult 10.3 eggs/day. The mean longevity of adult male was 10.8 days and of female 28 days. One female could lay 62 eggs in its life time.

The net reproductive rate, hypothetical F2 females and weekly multiplication rate were higher when *B. pallescens* was reared on *C. cephalonica* in comparison to the corresponding values when reared on *S. cerealella*, indicating that *B. pallescens* can be multiplied successfully on *C. cephalonica* eggs. The reproductive rate was highest at 28°C. Finite rate of increase and intrinsic rate of increase values were higher at 24 and 28°C and doubling time was minimum at these temperatures. However, the hypothetical F2 females and weekly multiplication rate were higher at 28°C indicating that *B. pallescens* can be multiplied efficiently by rearing them at constant temperature of 28°C.

Blaptostethus pallescens was evaluated against spider mites in the laboratory and nethouse. Nymphs fed more voraciously on mites than adults. *B. pallescens* nymphs were released against spider mites infesting okra plants. There was a 78% reduction in the mite population per leaf in the treated plants in comparison with control.

Orius tantillus nymph, adult male and female could feed on 42, 105 and 211, *Scirtothrips dorsalis*, respectively. When *O. tantillus* nymphs were released against *S. dorsalis* infesting rose in field conditions, there was a 50 to 77% reduction in buds/flowers infested by thrips.

Nucleopolyhedrovirus of *H. armigera*

Molasses 5% + Tinopal 0.2% + lampblack 0.1% was superior to all other adjuvants tested in increasing the persistence of *Hear*NPV. This was followed by crude sugar (5%) +Tinopal (0.2%). Studies conducted in the farmer's field for evaluating the formulation of *Hear*NPV against *H. armigera* on tomato revealed that the pest could be effectively controlled with the virus and the fruit damage was reduced and the larval mortality increased.

Shelf-life studies with wettable powder formulation of *Hear*NPV under both refrigerated and room temperatures revealed that both the formulations did not show any significant difference in the LC_{50} values at refrigerated conditions at different times of storage. However, the unformulated virus under room temperature recorded significantly higher LC_{50} values from the seventh month onwards of storage.

The wettable powder formulation packed with nitrogen under vacuum showed no loss of virulence during all the nine months of storage under room temperature. By the end of nine months (under room temperature) the LC_{50} value of unformulated virus suspension was 2.1 times more than wettable powder formulation packed with nitrogen under vacuum. The LT_{50} values progressively increased with increase in storage time. After nine months of storage, the unformulated virus recorded 129.7 (refrigerated condition) and 167.2 h (room temperature). Under room temperature wettable powder formulation packed under vacuum with nitrogen recorded least LT_{50} value of 145.7 h nine months after storage under room temperatures.

Establishment of insect cell lines

Primary cell lines with egg embryos of *Spodoptera litura* and *H. armigera* were established for *in vitro* cloning of NPV. The multiplied cells at 80% confluence were passaged and the viability of the cells assessed.

Isolation and characterization of indigenous *Bacillus thuringiensis* strains

The isolates designated as PDBCBT1 and PDBC-BNGBT1 at three different dilutions produced 100% mortality of *Plutella xylostella* (in cabbage leaf bioassay) and *H. armigera* (in diet bioassay). The toxicity of the isolates were on a par with the standards HD-1, C21h21 and Dipel.

Bacillus thuringiensis (PDBC-BT1) gave 100% mortality of first instar of *Chilo partellus, Sesamia inferens* and *Samia cynthia ricini* (eri silkworm). However, it showed less mortality against the third instar larvae of both insects.

SDS-PAGE analysis was done for the samples PDBCBT1, BNGT1 and HD-1 with the standard molecular weight protein marker at 75 volts in 10% gel. All the samples contained proteins with molecular weights of 30 kDa, 25 kDa and 17 kDa. A protein with 60-kDa molecular weight was observed for PDBC-BT1 and BNGT1 and a protein with 20-kDa molecular weight was obtained in PDBC-BT1 and HD-1. The HD-1 strain also showed 36 kDa and 13 kDa protein bands, which were not found in other lines. BNGT1 was unique showing other bands corresponding to 60kDa, 30kDa, 25kDa and 17kDa.

Agarose gel electrophoresis was done for samples PDBC-BT1, BNGT1 and HD-1 with standard molecular weight DNA marker. The total size of the DNA varied from 5804 bp to 7421 bp.

Studies on endophytic bacteria

The endophytic bacteria maintained as PDBC culture collection include *Bacillus megaterium, B. circulans, Bacillus* sp., *Erwinia herbicola, Enterobacter agglomerans, Pseudomonas aeruginosa, Cryptococcus albidus, Pseudomonas fluorescens* (19), *P. putida* (1), *Pseudomonas* sp. (7), *Bacillus subtilis* (2), *B. megaterium* (phosphate solubilizer) and fluorescent pseudomonads (28). *Bacillus* sp., *P. fluorescens* and *B. subtilis* were positive for chitinase expression.

Antibiotic resistance pattern for plant endophytic bacteria was developed using octodisks (HiMedia) containing eight different antibiotics at different concentrations. Out of the 25 root tissues tested, 10 tested positive for presence of *B. megaterium* and eleven for *Bacillus* sp. However, in leaf tissue, three samples showed the presence of *B. megaterium* and two *Bacillus* sp.

Chitinase activities were significantly higher in all bacteria-treated plants when compared to control. Highest chitinase activity of 2.53 U/g of plant tissue was observed in *B. megaterium*-treated and the lowest of 1.59 U/g was in control. However, *Bacillus* sp. treated plants also showed high ß-1,3-glucanase activity of 2.69 U/g. The next best was *P. fluorescens* with 2.44 U/g activity.

On tryptic soya agar (TSA) highest inhibition of 50% of was exhibited by the endophyte *Bacillus* sp. and the lowest of 25% was by *P. fluorescens* (rhizosphere isolate). On potato dextrose agar (PDA) the inhibition by all the bacteria was less and highest of 25% was seen in the endophyte *Bacillus* sp. Against *F. solani*, highest inhibition of 50% was exhibited by the endophyte *Bacillus* sp. on TSA and the next best was by the endophyte *Erwinia herbicola* (37.50%). On PDA, the inhibition by all the bacteria was less and highest of 33.3% was again seen in the endophyte *Bacillus* sp. The inhibition of *V. dahliae* on TSA by *Bacillus* sp. and *E. herbicola* was 41 to 48%, however on PDA all showed inihibition of 23 to 34%.

Maximum inhibition of 38% was exhibited with the methanol extracts of *B. subtilis* whereas extract of *P. fluorescens* showed 36% inhibition against *Fusarium vasinfectum*. Inhibition against *F. solani* was again maximum with extracts of *B. subtilis* (37%). However, 34% inhibition was shown by extracts of *Bacillus* sp. and *P. fluorescens*. Against *Verticillium dahliae* again maximum inhibition of 30% was observed with extracts of *B. subtilis*.

Pathogens for the biological suppression of phytophagous mites

Secondary metabolites of *Hirsutella thompsonii* produced 64.4% mortality of nymphs of the two-spotted spider mite, *Tetranychus urticae*, at the end of four days of incubation.

In the greenhouse, a significant reduction in the population *T. urticae* was achieved on the 4th day of spraying of *H. thompsonii* metabolites on rose plants. Eight days post treatment a reduction of 48.3% in live mite population was attained.

Beauveria bassiana, *H. thompsonii*, *Lecanicillium psalliotae* and *Metarhizium anisopliae* in combination with two adjuvants, viz. cold-water dispersible starch (0.2% final concentration) and glycerol (1% final concentration) decreased the population of *T. urticae* on okra under greenhouse conditions. *Hirsutella thompsonii* was the best, reducing the mite population by 85.2%.

Fungal antagonists

Addition of glycerol in the production medium at 3% concentration increased the retention of viability of propagules for up to 8 months ($2.6x10^{11}$/g) compared to control where glycerol was not added (10^6/g by 6th month).

Heat shock at 30°C for 30 or 60 minutes induced desiccation tolerance and helped in extending the shelf-life by additional one month. However, when there was drastic reduction in the water activity during the 6th month, the propagules were not tolerant to desiccation and sudden reduction of water activity. Heat shock could extend the shelf-life by additional one month. The heat shock has to be combined with a treatment that could retain the water activity in packing during storage.

Initial moisture content of 15% was found to help in retaining more viable propagules for longer period (by additional one month) compared to storing with initial moisture content of 8 or 10%. Though storing at 20% moisture content helped in retaining more number of propagules, the contamination levels were high. Three different packing methods, viz. normal packing, vacuum packing and nitrogen packing did not differ significantly with respect to viability of propagules when formulations were stored with different initial moisture levels.

Solid substrate-derived conidial formulations with or without substrate incorporation were found to have more shelf-life than formulations prepared using biomass from liquid fermentation. The viability of propagules at 10^8 colony-forming units (CFU)/g could be obtained in the solid substrate-derived formulations even after eight month. They were found to be tolerant to low water activity.

No significant differences were observed in the CFU counts of *B. bassiana* during five months of storage in the three packing methods followed and the three moistures levels tested.

Isolates of *Trichoderma* viride viz., TV-4, TV-23, TV- 25, TV-29 and TV-30 showed a good growth on carboxymethyl cellulose (CMC)-amended medium. The isolate TV-29 showed the maximum growth (113mg/50ml), followed by TV-25, TV-28 (both 61 mg/50ml), whereas the isolates TV-31 and TV-32 showed poor growth on PCWA medium. TV-32 exhibited high endo-1,4- glucanase activity in CMC-amended liquid medium. followed by TV-30, TV-14, TV-11 and TV-31. Regarding β-1,3- glucanase production TV-13 and TV-14 showed high activity followed by TV-34, TV-31, TV-32, TV-36, TV-5 and TV-30.

In *Phytophthora* cell wall-amended medium, isolates TV-32 and TV-35 showed the highest 1,4-glucanase activity followed by TV-25, TV-29, TV-23 and TV-31. β-(1,3)-glucanase activity was highest in TV-34, followed by TV-23, TV-29, TV-32, TV-28 and TV-25.

SDS-PAGE analysis was used to get the protein profile of extracellular proteins secreted by *T. viride* isolates in the CMC or *Phytophthora* cell wall-amended media. The proteins that were reported earlier to have glucanase activity could be observed in the present studies and confirmation with activity gel electrophoresis is in progress. Chitinase production was relatively higher in isolates TVS-Calicut, TVS-CPCRI and three PDBC isolates viz., TVS7, TVS9 and PDBC12.

When *T. virens* cultures were tested for their bioefficacy against *F. ciceri*, soil application of talc formulation of isolates TVS1, TVS3 and TVS-Calicut showed maximum germination and root colonisation besides root and shoot lengths. Though in all the plants treated with any of the isolates there was no symptom of wilt disease, based on germination and root colonization, TVS1 and TVS3 were found to be superior.

Entomopathogenic nematodes

A sponge method was found to be the best for transport retaining 90% viability of *Steinernema* spp. for 3-4 months and up to 85% viability of *Heterorhabditis* spp. for 2 months.

A granular formulation of entomopathogenic nematodes (EPN) was suitable for application in soil. Out of about 15 combinations, two supported *Heterorhabditis* populations for 60 days, 4 combinations for 30 days, 3 for 45 days and 2 for 15 days effectively. *Steinernema* populations (60%) were supported for 30 days effectively.

A cadaver formulation was found to be a viable method for application of EPN in field as the exit of progeny could be held up to 2 months by using specified formulations for *S. carpocapsae, S. abbasi* and *H. indica* and more so for *H. indica*.

Packing EPN formulations in 100% vacuum was not suitable compared to 75% vacuum or 75% nitrogen gas packing. Water activity of EPN formulation was not altered as a result of storage of formulation using different carrier materials for a period of 3 months.

In vivo production of EPN in wax moth larvae is regulated by humidity more than temperature and dosage of 50 and 100 IJs of *S. carpocapsae* and *H. indica* found suitable for maximum yield respectively.

Sandy soil was favourable for both *S.carpocapsae* and *H.indica*. Silty clay soil was not suitable for both nematode species. In general *S.carpocapsae* has adapted to all soil types tested.

Biological suppression of plant parasitic nematodes

Application of *Paecilomyces lilacinus* followed by *T. harzianum* @ 10^9 spores/pot (2kg soil) each before sowing, reduced seedling mortality to 8% due to *Fusarium*-reniform nematode wilt complex in cotton.

Application of a talc formulation of *Arthrobotrys oligospora* (PDBCAO1) to nematode-infested soil educed root infection by root-knot and reniform nematodes in tomato and cowpea, respectively. An 8-11% parasitisation of EPN juveniles in petri plate assay, indicated that *A. oligospora* was safe to EPN.

Talc formulations of *P. lilacinus* and *Pochonia chlamydosporia* recorded 92-96% and 88-92% spore viability at 12 months of storage at 8-10°C and ambient temperature and 4-8% moisture, respectively, in sealed aluminium sachets (lined).

Application of *P. lilacinus* and *P. chlamydosporia* talc-based formulation at 20 kg/acre in red gram resulted in 48-59 % reduction in cyst populations of pigeon pea cyst nematodes and an 18 to 21% increase in pigeonpea yield over untreated control in microplot trials at TNAU, Coimbatore and AAU, Anand.

Behavioural studies on natural enemies

The adults of *T. chilonis* conditioned for 6 hours to cues from cotton leaf volatiles could provide higher parasitism of *Corcyra cephalonica* eggs in comparison with unconditioned parasitoids.

The predatory efficiency of *Blaptostethus pallescens* on *H. armigera* eggs on chickpea leaves was studied. Highest predation of 90% was on washed leaves with moisture and minimum predation on unwashed leaves without moisture. Highest mortality of the predator occurred when 7-day-old nymphs were released on unwashed leaves without moisture, while mortality was much lower in the case of 10-day-old nymphs and adults. No predatory mortality occurred in washed leaves.

In the volatile profile of okra and chickpea, nothing was found having negative interaction with the predator. However, chickpea trichomes were observed to release malic acid and two ketones, i.e. 2-tridecanone and 2-undecanone, which are known for their toxicity.

The major volatiles were identified from cabbage, castor, sugarcane and *Ocimum* leaves. Fifteen plant volatiles evaluated in a bioassay revealed that adult *T. chilonis* responded positively to all the compounds evaluated at 0.05 and 0.1% concentrations.

The combination of caryophyllene pinene and linalool at 01:01:01% recorded highest oviposition by *C. carnea* followed by caryophyllene, pinene and linalool 0.1:01:0.2%.

Caryophyllene oxide at 0.1% recorded higher parasitisation by *T. chilonis*. Highest oviposition was recorded on the cotton plants exposed to the methyl salicylate for 24 and 48 h, compared to unexposed plants.

Storage studies conducted with different combinations of stablizers with tricosane revealed that treatments of scale extracts with tricosane and butylated hydroxy toluene (1: 2) recorded higher parasitisation after 30 days of storage.

Studies with *Trichogramma* spp.

A strain of *T. chilonis* tolerant to imidacloprid and monocrotophos was developed.

Among several species of *Trichogramma*, highest parasitism of *Sesamia inferens* eggs was seen in *T. japonicum* and *T. brassicae*. The developmental period ranged from 10–13 days and there was non significant difference between the species.

The ITS-2 region of several species of *Trichogramma* were sequenced and deposited with GenBank [accession nos. *T. chilonis* (DQ 220703), *T. brassicae* (DQ314611), *T. mwanzai* (DQ381279), *T. evanescens* (DQ381280), *T. brasiliense* (DQ381281), *T. dendrolimi* (DQ344045), *T. embryophagum* (DQ344044), *T. japonicum* (DQ 471294) and *T. pretiosum* (DQ 525178)].

The size of the ITS-2 region varied from 1000 bp – 500 bp in the different *Trichogramma* species. Based on this size variation three distict groups were formed: Group I included *Tr. armigera, T. achaeae, Tr. bactrae* the size of ITS-2 product varied from 700bp to 1000bp. Group II included *T. japonicum* and *T. embryophagum* the size of ITS-2 product varied from 570 to 600bp. Group III included *T. chilonis, T. pretiosum, T. evanascens, T. mwanzai, T. brasiliense, T. dendrolimi* and *T. brassicae*, the size of ITS-2 PCR product in these seven species varied from 500 to 550bp. ITS-2 sequences of different species were deposited in GenBank. The dendrogram constructed based on ITS-2 sequences generally tallied with that of traditional taxonomy.

Amongst three species studied, only *T. brasiliense* gave *Wolbachia* band indicating presence of *Wolbachia* in it. However, another thelytokus species *T. embryophagum* showed no *Wolbachia*, thereby indicating that in this species thelytoky is governed genetically.

Studies on *Chrysoperla carnea*

Four different populations of *Chrysoperla carnea* collected from Nagpur, Punjab and Delhi (lab) were reared on *C. cephalonica* eggs individually for 3 generations and their biological characters compared with those of the PDBC population. The survival of these populations ranged from 85 to 87.4 %. Maximum cocoon weight was recorded for Nagpur (10 mg) followed by Delhi (9 mg), Punjab (9 mg), and PDBC (9 mg). Highest longevity was recorded for Nagpur (60 days) and Delhi (60 days) followed by Punjab (46 days) and PDBC (46 days). Highest fecundity was recorded on *C. carnea* collected from Nagpur (411 eggs/ female) followed by Delhi (353), PDBC (338) and Punjab (264) populations. Longevity of *C. carnea* collected from different populations ranged from 46 to 60 days and highest was in Nagpur and Delhi followed by Punjab and PDBC populations.

Oral toxicity of the field recommended dosages of pesticides, viz. acephate (0.67 g/l), metasystox (2 ml/l), karate (0.6 ml/l), success (1.2 ml/l) and imidacloprid (0.5 ml/l) was tested by spraying on the UV-treated *C. cephalonica* eggs. The results revealed that the pesticides tested had no oral toxicity to *C. carnea* collected from Punjab, Delhi and PDBC. Imidacloprid (0.5 ml/l) and Acephate (0.67g/l) caused 20% mortality to Nagpur population of *C. carnea*. Quinalphos caused 100 % mortality of PDBC, Coimbatore, Delhi and Shimoga population of *C. carnea*.

Native PAGE of different *C. carnea* populations for esterase activity revealed differences between the population.

Molecular characterization of *C. carnea* (538bp) was done and the DNA sequence was submitted to National Centre for Biotechnology Information, USA (GenBank Accession No. DQ825504). Molecular characterization of *Chrysoperla carnea* (18-S RNA) collected from Delhi and *Mallada astur* (18-S RNA) from Bangalore was done.

Biological control of plant diseases

Yeast cultures isolated from mango fruit surface could restrict fruit rot to 27% while in control it was 60% in the mango variety Totapuri. In Dasheri, yeast culture (isolate 3) could restrict the damage to 50% by the 12th day of storage while in control the damage was 93% damage. Studies are in progress to identify better isolates and methods of treatment to enhance the level of control achieved.

Indian Agricultural Research Institute, New Delhi

Isolates of *B. thuringiensis* var. *kurstaki* along with standards were evaluated for their efficacy against the lepidopterans and were found to be highly toxic to neonates of *Earias vitella* and *Leucinodes orbonalis*. These isolates were positive for the presence of cry1, cry2, cry3 and cry4 on the basis of their PCR amplication with specific molecular markers.

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Oil-based formulations of *T. harzianum* and *P. fluorescens* suppressed the foliar disease and enhanced the yield compared to talc-based formulations in rice.

Strains of *T. harzianum* effective against *R. solani*, *S. rolfsii*, *Sclerotinia sclerotiorum* and *Fusarium oxysporum pisi* have been identified. PBAT-16 colonized the sclerotia of all the three fungal pathogens. Seed treatment with *T. harzianum* PBAT-39 and PBAT-38 were effective in suppressing the sheath blight, anthracnose and zonate leaf spot in sorghum and anthracnose in chilli when applied through seed/soil. Under greenhouse conditions, when applied as seed treatment, all the isolates reduced the disease incidence caused by both sclerotia-forming and non-sclerotia- forming pathogens.

Seed treatment alone or combined with foliar application of different biocontrol agents significantly reduced the rust severity and increased the grain yield of vegetable pea.

Seed treatment with *Trichoderma* resulted in significantly higher germination and green pod yield of pea, in large-scale field demonstrations in farmers' fields. Common Minimum Programme based IPM module, with reduced application of chemical pesticides without affecting yield by promoting the biocontrol agents, in tomato were conducted in Golapar - Chorgalia area of Haldwani district of Uttarakhand covering 28.5 acres area and 81 farmers. Biocontrol agents included in IPM modules significantly reduced the number of chemical applications. The benefit: cost ratio was higher for IPM plots.

Formulations of *T. harzianum* and *P. fluorescens* were developed in mineral oil (D-C Tron Plus). The population of *T. harzianum* as well as *P. fluorescens* was above 10^8 CFU per ml even after 10 months of storage.

In dual culture tests, three pathogens isolated from mango were antagonized by *Trichoderma* and *Pseudomonas*. But when used as fruit dip treatment both the antagonists were ineffective in controlling post-harvest fruit rot of mango.

Gene gun (biological ballistic) procedure was standardized for transforming *T. harzianum* strain PBAT-43. Hygromycin B-resistant transformants were recovered from *T. harzianum* strain PBAT-43. Southern analysis of hygromycin resistant progenies showed that the transforming sequences were integrated into the genome of the recipient strain.

Biological suppression of crop pests

Sugarcane

(i) *Pyrilla*

The incidence of sugarcane *Pyrilla* was low throughout the season in Punjab, so there was no need to redistribute *Epiricania melanoleuca* (PAU). Sporadic incidence of *Pyrilla* was observed in Haryana during August-October. The nymphal-adult parasitoid, *E. melanoleuca* and egg parasitoids were multiplied at Biopesticide Laboratory, RRS, Karnal and Central Biological Control Laboratories located on the premises of Co-operative Sugar Factories, Sonipat, Maham, Shahbad and Jind.

Releases made in 20,807 acres effectively controlled the pest (CCSHAU).

(ii) Scales

At Hissar, after two releases of predators *Chilocorus nigrita*, the IPM plot recorded lower incidence and intensity of sugarcane scale than the plots under check and farmers practice. At harvest, however, the differences were not statistically significant (CCSHAU).

(iii) Borers

The temperature-tolerant strain of *T. chilonis* developed by PDBC, Bangalore @50,000 per ha was on par with chemical control for the control of early shoot borer and it reduced the incidence by 53 to 56% in 40 ha demonstration plots. The cost: benefit ratio in release fields was higher than chemical control. The pooled data of two years revealed that releases of *T. chilonis* (tts) reduced the incidence of early shoot borer by 51.9% (PAU).

Twelve releases of *T. chilonis* at 10 days intervals in an area of 40 ha against *Chilo auricilius* during July to October @ 50,000 per ha reduced the incidence by 65.7%. The parasitisation in release fields was 59.1% as compared to 4.9% in the control. The pooled data of two years (2005-06) revealed that *T. chilonis* reduced the incidence of stalk borer by 63.3% (PAU).

Releases of *T. chilonis* in an area of 3,500 acres in collaboration with two sugar mills of the state resulted in reduction of stalk borer incidence by 42.3%. The pooled data of two years (2005-06) revealed a 48.9% reduction in incidence of stalk borer (PAU).

Six releases of *T. japonicum* during April - June @ 50,000 per ha proved as effective as chemical control for the control of *Scirpophaga excerptalis* and it reduced the incidence by 51.2 % with a higher cost: benefit ratio (PAU).

In Jorhat, release of *T. chilonis* had good impact in reducing the incidence of Plassey borer, *Chilo tumidicostalis* and in increasing % egg parasitism. The treatment plot registered a yield of 79.2 t/ha in comparison to 58.0 t/ha in farmers' fields (AAU(J)).

(iv) White grubs

At Hissar, the lowest number of white grubs was recorded in sugarcane plots treated with FYM containing *B. bassian,* @ 6×10^{10} conidia/kg. The infectivity was also maximum in the grubs collected from the above treatment plots.

(v) Woolly aphid

In Assam, the maximum mean number of sugarcane woolly aphid was in September, followed by August and December. The population of *Dipha aphidivora*, *Micromus* sp. and *Syrphid* spp. was found to be maximum during September and *Encarsia flavoscutellum* during December. In general the aphid infestation was not very high during 2006-07 due to the presence of natural enemies (AAU(J)).

In Maharashtra, the pest infestation was recorded only in 6.9% of cropped area during 2006-07. The pest was active in Aurangabad division with 28.1% infested area. However, per cent infestation and intensity rating was low in Western Maharashtra wherein the activity of the predators, *Micromus igorotus* and *D. aphidivora* was adequate (MPKV).

The population build up of *D. aphidivora*, *Micromus* and syrphid showed significant positive correlation with the maximum and minimum temperature. Relative humidity (morning) had a positive significant correlation with the population of *Encarsia* in Golaghat district of Assam (AAU(J)).

The pooled results obtained from last 2 years in Andhra Pradesh suggested that two peaks of the woolly aphid, first during June- August and second during November –January were noticed till 05-06. Among the various sugarcane growing areas of the state, Southern Telangana Zone (STZ) and Northern Telangana Zone (NTZ) recorded more incidence than the coastal districts. *D. aphidivora* is a predominant predator but not present in the areas where insecticides were used. Peak incidence of *D. aphidivora* was noticed during November–January survey in STZ till 2005-06. In 2006-07, the populations were almost nil indicating the overall decline in the pest as well as its predominant natural enemy, *D. aphidivora* (ANGRAU).

At Coimbatore, the activity of the woolly aphid and its predator *D. aphidivora* was generally higher during July – December 2006. *Micromus* activity was generally low (SBI).

The dominant *D. aphidivora* appeared in higher numbers during October and November 2006. Rainfall and wind speed showed significant negative correlation with the woolly aphid population (TNAU).

Planting of cane at wider row space (45:120 cm) proved superior to the conventional planting (75 cm distances) in minimizing the intensity of *C. lanigera* infestation. Maximum population of *C. lanigera* and *D. aphidivora* was recorded during last week of January 2007. The per cent loss in sugar recovery ranged from 9.28 (CoS 8436) to 18.44 (CoS 767) and 10.54 (CoS 8436) to 19.75 (CoS 767) (IISR).

Pooled results of 2005-06 and 2006-07 at AP showed that crop management practices against the aphid with Recommended agronomic practices fared better than farmers practice (ANGRAU).

At MPKV, Pune, mass production of *D. aphidivora* on the aphid was carried out in bamboo shade nets. Seven-month-old crop covered with shade net yielded av. 2,540 larvae/ pupae of *D. aphidivora* per shade net within 2 months. The laboratory mass culture technique for rearing *D. aphidivora* was successful at SBI.

At TNAU, when the woolly aphid infestation reached 90% of leaf coverage (40 days from date of inoculation), 100 *D. aphidivora*/day could be harvested. Maximum number of *D. aphidivora* could be harvested between 50 – 55 days after inoculation of larvae.

In Maharashtra, inoculative release of *D. aphidivora* @ 1,000 larvae per ha at 10 spots effectively reduced the woolly aphid population within 60 days (MPKV). Field evaluation/demonstration trials at Coimbatore, Puthur, Vellalore and Elayamuthur indicated that *D. aphidivora* releases significantly reduced the aphid intensity (TNAU & SBI). The rate of release of *D. aphidivora* has been fixed at 1000 larvae/ha (TNAU).

Life table studies of SWA indicated that the net reproductive rate (R_0) was 49.6 nymphs/female/ generation on sugarcane in a generation time (T_c) of 25 days. The innate capacity (r_m) for increase in numbers was 0.33 nymphs per female per day and the population would be able to multiply 10.1 times per week. The nymph and adults contributed 91.4 and 0.02 % respectively, to the population of stable age distribution (MPKV).

Encarsia flavoscutellum failed to establish in AP mainly due to unfavourable weather conditions and absence of host insect during 2006-2007 (ANGRAU). In Coimbatore, *Encarsia* establishment was confirmed 11 months post release and the adults were observed to disperse up to 3 kms from release spots in all directions (TNAU).

Cotton

There was no significant difference in sucking pests and predators among the *Bt* and Non- *Bt* hybrids, as the pest population was low at Punjab. The highest yield was recorded in RCH 134 *Bt* followed by MRCH 6301 *Bt* and Ankur 651 *Bt* hybrids (PAU).

On *Bt* cotton, BIPM package was effective in suppressing sucking pest population with significant increase in the coccinellid and chrysopid numbers. The module was comparable to *Bt* cotton with existing package with respect to reduction in bollworm damage and increase in seed cotton yield (MPKV).

At Anand, *Bt* cotton with bio-intensive pest management (BIPM) practices effectively suppressed the cotton pests and provided maximum net return. (AAU(A)).

In the trial of ANGRAU, the sucking pest population was comparatively lower in *Bt* cotton with BIPM than in Farmers Practice. *Helicoverpa armigera* damage was less in *Bt* cotton with BIPM and with FP, while non-*Bt* was considerably damaged by this pest. The net returns were also more in *Bt* cotton with BIPM.

At Coimbatore, *Bt*-BIPM plots recorded the lowest number of sucking pest and lowest extent of damage, higher number of natural enemies and higher yield (TNAU).

Natural enemies population was higher in habitat management plot followed by the BIPM and was very low in insecticidal control. Highest seed cotton yield however was obtained in insecticidal control, which was significantly higher than habitat management and BIPM. Pooled data also revealed a similar trend (PAU).

Highest net return with highest yield, natural enemy population and egg parasitism with lowest population of pests and damage was in the treatment with *Trichoderma* seed treatment + cotton interspersed with *C. occidentalis* (6:1) + 10% planting of maize and zinnia @ 10% + one release of biocontrol (AAU(A)).

Four paired rows of cotton interspersed with one row each of cowpea and marigold + paired border row with sorghum reduced the pest populations with more of natural enemy activity. The yield was also comparatively higher with better net returns (ANGRAU).

Natural enemy activity was minimal in Mallika *Bt* followed by Bunny. Coccinellids, chrysopids, bugs and spiders were the most abundant natural enemies in *Bt* cotton ecosystem (ANGRAU).

A field experiment on the utility of kairomones to increase the efficiency of trichogrammatids on cotton at the Raichur campus of UAS (Dharwad) in collaboration with PDBC revealed that pentacosane + tricosane treated plot enhanced the efficacy of *T. chilonis* against the boll worms and increased the seed cotton yield.

Tobacco

In field crop of tobacco, *Ha*NPV sprayed in the evening hours with or without adjuvants was effective in suppressing leaf damage by *H. armigera*. Entomofungal pathogens *N. rileyi* and *B. bassiana* and NSKS were equally effective in containing the leaf damage caused by *Spodoptera exigua* on tobacco. The trap crops *Tagetes* and castor effectively suppressed damage caused by *H. armigera* and *S. litura* and increased natural enemy population on tobacco.

Pulses

BIPM against *S. litura* and leaf webber, *Aproarema modicella*, in soybean was significantly effective over farmer's practice (CTRI). With the adoption of BIPM package on soybean, additional yield of 4.6 q/ha could be realised (NRCS).

Laboratory bioassays at AAU, Anand indicated that DOR *Bt* formulation was effective in controlling the pod borers of pigeonpea. DOR *Bt* caused 52.3% mortality of *Helicoverpa* and 63.2% mortality of *Maruca testulalis* in lab studies at ANGRAU. At TNAU, *M. testulalis* was observed to be highly susceptible to DOR *Bt* in laboratory tests.

Field tests against pod borers of pigeonpea revealed that DOR *Bt* at 2kg/ha was inferior to NSKE 5% and endosulfan 0.07% (TNAU). For control of slug caterpiller (*Lampides* sp.), endosulfan @ 0.07% gave best results and this was on par with application of DOR *Bt* @ 2.0 kg/ha. For control of plume moth (*Exelastes atomosa*), endosulfan @ 0.07% and DOR *Bt* @ 2.0 kg were on par (AAU(A)).

Pooled data revealed that pigeonpea pod damage was minimum and grain yield was highest in endosulfan 0.07% and on par with DOR *Bt* @ 2.0 kg/ha. Highest net returns could be obtained from endosulfan 0.07% followed by NSKE 5% (AAU(A)).

Rice

Experiments conducted in Kerala (KAU), Punjab (PAU) and Jorhat (AAU) revealed that DOR *Bt* was effective and on par with chemical control in managing stem borer and rice leaf folder larvae. Significantly high grain yield was recorded in *Bt* treatments followed by chemical control.

Three releases of *T. chilonis* and *T. japonicum* each @ 1,00,000/ ha, starting 30 DAT proved effective in controlling leaf folder and stem borer on organic rice and basmati rice. The pooled analysis of the data for three years (2004 to 2006) revealed that pest control in organic farming was at par with recommended practices. In large scale (10 ha) demonstration IPM (one application of cartap hydrochloride, 25kg/ha and 7 weekly releases of *T. chilonis* and *T. japonicum* each @ 1,00,000/ ha) proved as effective as chemical control (Cartap hydrochloride @ 25kg/ha, 30, 50 and 70 DAT) for the control of leaf folder and stem borer of rice. The pooled data of three years (2004 to 2006) revealed that the incidence of leaf folder and stem borer and grain yield in BIPM was on a par with chemical control (PAU).

Validation of BIPM in organic rice production carried out in four seasons during 2005-07 revealed that predator population was significantly high in organic farming plot. The yield was on par with conventional rice (KAU).

BIPM gave higher grain yield than farmers practice. Further, the soil analysis indicated that the field under biointensive trial contains 0.37% of organic carbon in comparison with 0.35% in farmers' practices trial (NCIPM).

At Jorhat, there was a significant reduction in pest population and crop damage with maximum yield and highest cost: benefit ratio in treatment with organic package (AAU(J)).

The BIPM in rice has been practiced in an area of 3000 acres in Adat Panchayath in Thrissur district and *Trichogramma* spp. @ one lakh/ha has been recommended for the management of rice leaf folder and stem borer (KAU).

Oilseeds

Damage by mustard sawfly in chemical control plots was not significantly different from DOR Bt-treated plots. However, the maximum yield was recorded in the commercial *Bt* treatment, which was at par with DOR *Bt* 2.0 kg and chemical control treatments (AAU(J)).

Coconut

Hirsutella thompsonii in combination with the three adjuvants, viz. glycerol, yeast extract powder and malt extract broth (MEB) significantly reduced the post-treatment population of the coconut mite. The fungus was able to cause disease in the mite on all the sprayed trees as evidenced during the post-treatment sampling. The maximum reduction of 97.2% in post-treatment population of the coconut mite was brought about by the fungus in combination with MEB (PDBC).

At CPCRI Farm, Kasaragod there was no significant difference between the treatments with *H. thompsonii* or periods of application (CPCRI). KAU trials indicated that *H. thompsonii* treatments and dicofol were on par and significantly reduced the population of coconut mite when compared with control (KAU).

Bracon spp. collected from different regions were compared. Kasaragod (Kerala) and Pitappall (Orissa) collections were superior to others with regard to longevity, parasitism and fecundity. Female progeny production was higher in Thiruvananthapuram and Orissa cultures (CPCRI).

Releases of *T. embryophagum*, *G. nephantidis* and *C. exiguus* against coconut leaf caterpillar were made against the black headed caterpillar for two seasons and the results show that pest population was reduced significantly after release of biocontrol agents (KAU).

Combined use of *Oryctes* baculovirus + *M. anisopliae* + pheromone trap did not give better control than the virus treatment (CPCRI).

The management of rhinoceros grubs in cowdung pits using the fungus *M. anisopliae* var. *major* resulted in 100% mortality of the grubs in treated media (KAU).

Tropical fruit crops

Application of *B. thuringiensis* @ 1ml/l at weekly intervals with the initiation of new flesh was observed to significantly reduce *Phyllocnistic citrella* in pomello. On sapota, the aphelinid parasitoid *Coccophagus* sp. was able to keep the *Coccus viridis* population under check (IIHR).

Releasing *Cryptolaemus montrouzieri* during off-season significantly reduced the infestation of mealybugs, *Planococcus citri*, *Ferrisia virgata* and *Maconellicoccus hirsutus* on custard apple. Among the new molecules tested for their safety to *C. montrouzieri*, imidacloprid 0.5ml/l, abamectin 0.5ml/l, fluvalinate 0.5ml/l, profenophos 1ml/l , ethnfenprox 1ml/l , flufenoxuron 1ml were observed to be less toxic to the predator. Residual toxicity studies indicated that profenophos + cypermethrin proved to be harmless on 7th day of application while bifenthrin proved to be safe on 14th day of application to the adult beetles. A method to mass multiply *Encarsia guadeloupae* was standardized under glasshouse conditions on potted plants of guava, by which the culture was available throughout the year (IIHR).

In a demonstration, release of *C. montrouzieri* @5000 larvae/ha against pink mealybug *M. hirsutus* on grapes at Tuljapur near Solapur in Maharashtra reduced the mealybug infestation from 70.5% to 0.75% within a year (IIHR/NRCG).

Temperate fruit crops

Average % parasitism of San Jose scale was found increasing from 7 to 25 in IPM managed orchard, from March to September, as a result of 7 releases (May to July) of *Encarsia perniciosi* @ 1000 individuals/ tree. Natural parasitism of the pest by *E. perniciosi* and *Aphytis proclia* in unmanaged orchard was also recorded increasing steadily from 6.02 to 18.51 % during similar period of observations. However, in farmers' orchards, considerably low level of parasitism was observed (SKUAS&T).

Heterorhabditis bacteriophora (2.83 lakhs IJs/tree) and *Steinernema feltiae* (2.9 lakhs IJs/ tree), failed to control the root form of the woolly apple aphid. However, when *S. feltiae* (200 IJs/ml) was sprayed on the apple tree, there was a reduction in aphid colonies, their mean size and coverage on the treated trees in comparison to control. In laboratory testing, first instar grubs of the apple root borer, *Dorysthenes hugelii* were sensitive to *S. feltiae* applied at 2 x 10^5 IJs/m^2 (Dr.YSPUH&F).

The predator, *Amblyseius longispinosus*, could be multiplied during winter on *Tetranychus telarius* on excised mite-infested rose leaves kept on wet sponge in petri plates. A predatory mite *Amblyseius* (*Euseius*) *delhiensis* has been recorded feeding on *T. telarius* and the greenhouse whitefly nymphs, *Trialeurodes vaporariorum* and another predatory mite, *A. indirae* was observed on mango leaves among mycosed nymphs of the mango hopper (Dr.YSPUH&F).

Various microbial pesticides, viz. *V. lecanii, H. thompsonii, B. bassiana* and *M. anisopliae*, when evaluated against the European red mite, *Panonychus ulmi*, under laboratory conditions, the highest mortality was observed with *V. lecanii* and *H. thompsonii*, followed by *M. anisopliae* and *B. bassiana* (SKUAS&T).

Vegetable crops

DOR *Bt* @ 2 kg/ha was on par with chemical control for the management of *Earias* sp. on okra. Chemical control was on par with DOR *Bt* @ 2 kg/ ha for management of *L. orbolnalis*. EPN@ 2 billion/ ha gave moderate control of the pest (PAU).

Trials conducted during two seasons indicated significantly high fruit yield and low brinjal fruit borer infestation in DOR *Bt* 2 kg/ha treated plot (KAU).

Trials conducted by SDAU indicated that IPM plots were superior to control plots with respect to head damage in cabbage and yield. However, IPM plots were inferior to chemical control plots.

All the doses of DOR *Bt* and Halt were on par with chemical control for the control of Diamond back moth on cabbage (PAU)

Spraying of the biological control agents (DOR *Bt* @ 1g/l, *M. anisopliae* @ (1x10^9 spores/ ml), *B. bassiania* @ 15g/l (formulated), *S. carpocapsae* @ 1 billion/ha at weekly intervals starting from primodial head formation (a total of 5 sprays) recorded significant reduction in mean DBM larval population as compared to control. Two sprays of *Bt* @ 1g/l at fortnight intervals + 6 weekly releases of egg parasitoid *Trichogramma brassicae* (@ 40–60 thousand adults/week, equalling to a total of 3,00,000 adults/ ha), was observed to significantly reduce DBM population on cabbage, with an increase in marketable yield as compared to control (IIHR).

The highest yield and B:C ratio were recorded in the cabbage plots treated with endosulfan followed by DOR *Bt* treated plots. The larval parasitism was higher in *Bt* treated plots and control compared to endosulfan treated plots (MPKV).

Highest yield of cabbage and B:C ratio were obtained in Spinosad treatment and DOR *Bt* at 1kg/ ha, which were superior to releases of *T. brassicae* (MPKV).

Application of DOR *Bt* (1g/l), *Metarhizium anisopliae* (1x10^9 spores/ml) *Steinernema carpocapsae* (1 billion/ha) at weekly intervals on spotting of larvae resulted in a significant reduction in larval population of *Diaphania indica* on gherkins. A significant reduction in fruits damaged at harvest was recorded in all the treatments as compared to control (IIHR).

Among the two host plants tried for mass rearing of *Thrips tabaci* (Frenchbean pods and onion sheath), onion sheath was found to be a suitable host material. Adult anthocorid *Orius tantillius* fed on 6-25 (mean 13.1) second instar larvae of *Scirtothrips dorsalis* per day and survived for 7 – 22 days (IIHR).

Bacillus thuringiensis subspecies *kurstaki* at 1kg/ha and EcoNeem Plus at 2ml/l was effective in suppressing early instar larvae of *Pieris brassicae* on cole crops. In laboratory experiment, conidial suspension of *Beauveria brongniartii* (local isolate) applied @ 10^{14} conidia/ha to ice cream cups each containing one second instar grub of *B. coriacea* caused maximum mortality of 70 % in 4 weeks from date of treatment and out of these, 60% died due to mycosis. In a field experiment laid out at government potato farm, Shilaroo (Shimla district) for suppression of white grub, *Brahmina coriacea*, minimum population (2.2/m row) was recorded in *B. brongniartii* treated plots (10^{14} conidia/ha) (Dr.YSPUH&F).

Weeds

In Kerala and Tamil Nadu no natural enemies of *Cyperus rotundus* could be collected. At Ludhiana, 2% fungal infection was recorded during second fortnight of July and 1 to 3% during October from the field collected samples of *C. rotundus*. One lepidopteran borer could be recorded as a natural enemy of *C. rotundus* at Jorhat, Golaghat and Nagaon districts in Assam during 2006.

White grubs

Studies were conducted on the bio-efficacy of local strain of EPN, *Steinernema glaseri* against third instar grubs of *Holotrichia longipennis* under lab conditions at GBPUA&T, Ranichauri Centre. The highest inoculation dose gave 90% cumulative mortality on 7th day from the date of application.

Pests of polyhouse crops

Fungal formulations viz. *V. lecanii*, *H. thompsonii*, *M. anisopliae* and *B. bassiana* and chemical control were on par in reducing the population of thrips (*Frankliniella* sp.) on Gerbera plants in polyhouses (KAU).

Imidacloprid 0.00925% and local isolate of *Paecilomyces fumosoroseus* at 10^{11} conidia/l water proved equally effective in managing greenhouse whitefly infesting cucumber crop in polyhouse within 15 days of the treatment (Dr.YSPUH&F).

M. anisopliae was observed to be most effective against thrips on chilli in polyhouse (MPKV).

Evaluation of spray of *V. lecanii* for the control of white fly in gerbera indicated that the sprays were effective for a week, after which the population increased (NCIPM).

Establishment of mass production units

At KAU, an insect pathology laboratory was established to produce *B. bassiana*, *M. anisopliae* and *V. lecanii*. This is to help in teaching and training of students, farmers and extension workers. *M. anisopliae* var. *major* is produced in bulk quantities for field level demonstrations on management of rhinoceros beetle.

At TNAU, large-scale production and supply of the parasitoid, *Bracon hebetor* was taken up for the management of *O. arenosella* on coconut. Totally 2.88 million parasitoids were supplied to the Joint Director of Agriculture, Erode and the releases were made in Arachalur, Modakarichi block, Erode district where 96,040 trees were brought under the biocontrol.

In Haryana, the biocontrol laboratories attached to Cooperative Sugar Factories produced 23,572 egg-masses and 32,774 cocoons of *E. melanoleuca*, 13,778 egg masses of egg parasitoid of *P. perpusilla* 30,82,54,000 parasitised eggs of *Trichogramma chilonis* and 2,08,04,000 of *T. japonicum* and white muscardine *B. bassiana* and *B. brongniarti* were produced for experimental purpose (CCSHAU).

At MPKV, Pune cultures of four host insects, six parasitoids, three predators and two NPV were continuously maintained. Bioagents were supplied to research units and farmers as per need.

Transfer of technology

A simple design and technology was developed for production of talc-based formulations of antagonistic fungi and the technology was sold on non-exclusive basis to private companies. The use of trap crops like marigold and castor for the management of *S. litura* and *H. armigera*, respectively, in tobacco has been assessed and validated in farmers fields during 2005-07. Mass multiplication method for *P. fluorescens* on cowdung developed and validated and submitted for patenting. The BIPM package for the management of rice leaf folder and stem borer by the release of

Trichogramma spp. @ one lakh/ha has been validated in an area of 3000 acres in Adat Panchayath in Thrissur District. A video documentary on this technology has been produced during 2006-07.

Human resource development

Ten scientist of PDBC have attended different training programmes like Project formulation and evaluation, Molecular characterization of natural enemies and Biosystematics of Chalcid parasitoids. Coccinellid collections at the Australian National Insect Collection (ANIC), CSIRO Entomology, Canberra, Australia, were studied, with particular emphasis on the Australasian and Oriental / Indian fauna. Three scientists participated in international workshops held overseas. The Project Directorate organized 20 training programmes on different aspects of biological control during the year 2006-07 in which 79 scientists representing ICAR Institutes, SAUs, State Department of Agriculture and Horticulture and commercial production units participated.

Revenue generation

A revenue of Rs. 13.81 lakhs was generated by the Project Directorate, which included consultancy, sale of technical bulletins and natural enemies.

Publications

Sixty-eight research papers were published in scientific journals. Sixty research papers were presented during symposia/ seminars/ workshops. Twelve book chapters/ scientific reviews were written and 22 popular articles/ technical and extension bulletins were published.

4. INTRODUCTION

Brief history

The AICRP on Biological Control of Crop Pests and Weeds was initiated in 1977 under the aegis of the ICAR, New Delhi, with funds from the Department of Science and Technology, Government of India. Within two years (1979), the 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 the present Project Directorate of Biological Control with headquarters at Bangalore. The Project Directorate started functioning on 19 October 1993. The AICRP started with 13 centres initially and has now 16 centres, all functioning under the Project Directorate.

Past achievements

Basic research

- Eighty-nine exotic natural enemies have been studied for utilization against alien pests, out of which 59 could be successfully multiplied in the laboratory, 51 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*, introduced from Lakshadweep has colonized in peninsular India, displacing the earlier introduced *Encarsia* sp. nr. *meritoria*.
- *Trichogramma brassicae*, an egg parasitoid, introduced from Canada was successfully quarantined and found suitable for biological control of *Plutella xylostella* on cole crops.
- *Curinus coeruleus* (Origin: South America), the coccinellid predator introduced from Thailand in 1988, colonized successfully on subabul psyllid, *Heteropsylla cubana*.
- *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 suppressing parthenium growth during rainy season.
- The stem gallfly, *Cecidochares connexa*, was introduced from Indonesia in 2002 and successfully field released and established on *Chromolaena odorata* in 2005. The gall fly is suppressing the growth of *C. odorataa* and has spread to a distance of 2 km from the release spot.
- *Puccinia spegazzinii*, the rust fungus specific to *Mikania micrantha* imported from CABI, UK in 2003 was successfully quarantined in NBPGR, New Delhi and open field releases were made in Kerala and

Assam where the establishment is being monitored.

- Biosystematic studies were carried out on 275 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 were 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.
- *Sitotroga cerealella* eggs proved to be the most suitable for rearing *Orius tantillus* and *Corcyra cephalonica* eggs for *Blaptostethus pallescens*.
- 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*
- The Coccinellid predators, *Cryptolaemus montrouzieri*, *Cheilomenes sexmaculata* and *Chilocorus nigrita* were successfully mass-produced on semi-synthetic diets.
- 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 and deployed for the management of sugarcane woolly aphid, *Ceratovacuna lanigera*.
- A novel technique of modified atmosphere packing of *Corcyra cephalonica* eggs followed by low temperature storage at 8±1°C has been developed to extend the shelf life.
- 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*, *Leptomastix 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 *T. chilonis* tolerant to multiple-insecticides 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 the 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 *Pseudomonas putida*-PDBCAB 19) of plant pathogens have been released for commercial production after intensive studies.

- Bacterial antagonists, particularly *Pseudomonas cepacia* (starin N 24), suppressed successfully *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 were identified. *S. carpocapsae* @ 1.25-5 billion/ha proved effective against the brinjal shoot and fruit borer, *Leucinodes orbonalis*. Talc-based and alginate-capsule formulations of *S. carpocapsae* and *H. indica* were effective against *S. litura* in tobacco. A sponge formulation was found suitable for transport retaining 90% viability of *Steinernema* spp. for 3-4 months and 85% viability of *Heterorhabditis* spp. for 2 months.
- 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 chlamydosporia* was effective in sandy loam soil.
- Molecular identity of native isolates of *P. chlamydosporia* at PDBC was established through sequencing the â-tubulin gene (1 to 233 bases) and registered in the Genbank, NCBI, Maryland, USA.
- *Bacillus thuringiensis* isolate PDBC-BT1 caused 100% mortality of first instars of *Plutella xylostella, Chilo partellus* and *Sesamia inferens*. *B. thuringiensis* isolate PDBC-BNGBT 1 caused complete mortality of *Helicoverpa armigera*.
- '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, Micromus igorotus* and *Dipha aphidivora* effectively controlled 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 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) controlled the rice stem borer and increased the grain and net profit.
- IPM module comprising of need-based use of oxydemeton methyl (0.03%), releases of *C. carnea, T. chilonis* and spray of *Ha*NPV controlled the sucking pests and boll worms and increased the yields of seed cotton and conserved natural enemies.
- 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 *Telenomus remus* @ 100,000/ha and three sprays of *Sl*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 *T. 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 trunk 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 the 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 specialized laboratories for Biosystematics, Introduction and Quarantine, Mass Production, Pathology, Entomophagous Insect Behaviour Studies, Biotechnology and a Technical and Documentation Cell (Fig. 1).

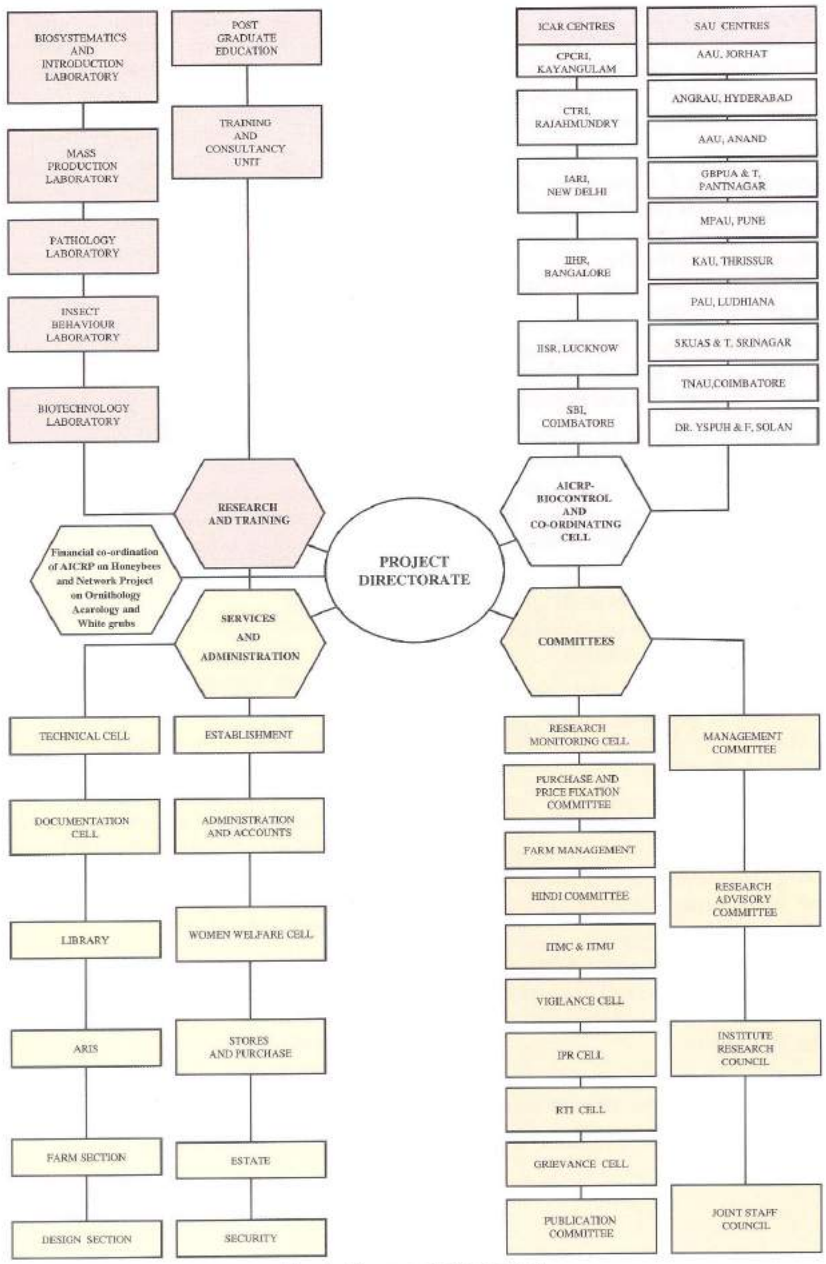

Fig. 1. The organizational chart

Financial statement (2006-07) (Rs.in lakhs)

Project Directorate of Biological Control, Bangalore

Head	Plan	Non-plan	Total
Pay & allowances	0.00	151.49	151.49
TA	3.00	3.00	6.00
Other charges including equipment	34.69	55.00	89.69
Information Technology	1.00	-	1.00
Works/petty works	140.90	16.64	157.54
HRD	4.00	-	4.00
OTA	-	0.15	0.15
Total	**183.59**	**226.28**	**409.87**

AICRP Centres (ICAR share only) expenditure (2006-07)

Name of the centre	Expenditure
AAU, Anand	11.92
AAU, Jorhat	5.70
ANGRAU, Hyderabad	13.95
Dr.YSPUH&F, Solan	2.00
GBPUA&T, Pantnagar	1.00
KAU, Thrissur	6.64
MPKV, Pune	0.00
PAU, Ludhiana	14.66
SKUAS&T, Srinagar	1.00
TNAU, Coimbatore	3.50
Total	**60.37**

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

5. RESEARCH ACHIEVEMENTS

5.1. BASIC RESEARCH

5.1.1. Project Directorate of Biological Control, Bangalore

(i) Biosystematic studies on predatory coccinellidae

(a) Taxonomic studies

Taxonomic studies were initiated on the subfamilies Scymninae and Sticholotidinae. *Halyzia dejavu*, a new sibling species of *H. straminea* distributed in India and Nepal was described. This species was hitherto misidentified as *H. straminea*. The identity of the type species, *Synona melanaria*, which was uncertain, was resolved based on available evidence. A female syntype from Indonesia (Paris Museum) was designated as the lectotype based on comparison with specimens of *Synona* from Indonesia. The status of Indian species, *S. rougeti* and *S. martini*, was resolved. The species commonly identified as *S. melanaria* ab. *rougeti* was found to be a distinct species based on the examination of type material of *S. rougeti* and it was described under a new name. *Synona melanopepla* was found to be the senior-most available name for the Indian species hitherto misidentified as *S. rougeti*. The genus *Scymnodes* (Coccinellidae: Scymninae), endemic to Australasia and New Guinea, was reviewed. The two subgenera presently recognized, namely, *Scymnodes* (*Scymnodes*) and *Scymnodes* (*Apolinus*), were raised to distinct genera in view of the marked differences in adult and larval morphology. Sixteen species of *Scymnodes* and eight species of *Apolinus* were treated including 12 new species. The species studied included *S. koebelei*, *S. difficilis*, *S. consimilis*, *S. bellus*, *S. fulvohirtus*, *S. obscuricollis*, *S. styx*, *S. laticollis*, *S. lividigaster*, *S. terminalis*, *S. cribratus*, *S. rotundus* and *S. longicornis*. The species of *Rhynchortalia* (in part) and *Cryptolaemus* s.l. (in part) were studied and about 25 new species were recorded from the Australasian region. For the first time ever in the family Coccinellidae, presence of a stridulatory apparatus was recorded in the males of some species belonging to *Cryptolaemus* s.l.

(b) New distribution records

Stictobura melanaria, a rare species, was recorded for the first time from Karnataka and Tamil Nadu. *Ghanius karachiensis* was recorded for the first time from Maharashtra and Tamil Nadu, which are new distribution records for this species. The larva of *G. karachiensis* was found to be very unusual as it has one-segmented maxillary palpi unlike other members of the subfamily. New colour morphs of *Buprestodera mimetica* and *Cryptogonus kapuri* were recorded for the first time. A new species of *Horniolus* was recorded from Karnataka and studied in detail with illustrations.

(c) Studies on coccinellids in other collections

Coccinellid collections at the Australian National Insect Collection (ANIC), Canberra, Australia, were studied with particular emphasis on Oriental genera and species, including those occurring in the Indian subcontinent. Primary types and hundreds of specimens of species belonging to the groups mentioned earlier from various museums such as British Museum, Bishop Museum, Paris Museum, Stuttgart Museum, Basel Museum, and ANIC were studied at CSIRO Entomology, Canberra, Australia.

(d) Identification tools

Halyzia dejavu (Fig. 2), *H. straminea* and *Ghanius karachiensis* were added to the identification guide for common coccinellids of the Indian subcontinent. About 25 photographs were added to the website on the Coccinellidae of the Indian region, featuring image galleries of common species, their natural enemies and other images.

Fig. 2. *Halyzia dejavu*

(ii) Biosystematics of *Trichogramma* and *Trichogrammatoidea*

Trichogramma flandersi and *T. chilonis* were collected on *Chilo infuscatellus*, *T. japonicum* on *Scirpophaga incertulas*, *T. hesperidis* on Hesperiidae on rice, and *Trichogrammatoidea armigera* on *H. armigera* on pigeopea, *T. chilonis* on *L. boectius* on field bean, and all these cultures are maintained on eggs of *Corcyra cephalonica*. A species of *Trichogramma* was collected on eggs of Sphingidae and another species on the eggs of bruchid.

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

Field observations at GKVK, Bangalore revealed that the gall density caused by the introduced gall fly *Cecidochares connexa* on the Siam weed, *Chromolaena odorata* increased from 2.5 galls (April 2006) to 98.3 (November 2006) confirming its establishment (Fig. 3). The insect could spread to a distance of 1 km towards east. Similar studies at Tataguni village revealed an increase in gall density from 1.6 (April 2006) to 156 galls (October 2006) (Fig.4). The gallfly could spread to a distance of 2 km towards north-east.

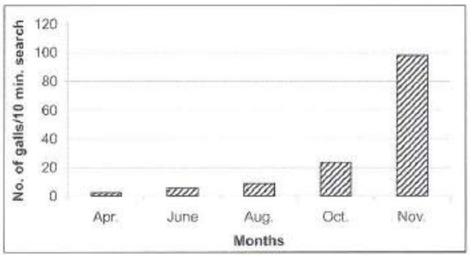

Fig. 3. Gall density at UAS, GKVK, Bangalore north during 2006

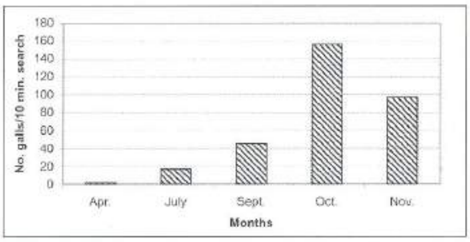

Fig. 4. Gall density at Tataguni village, Bangalore south during 2006

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

(a) Evaluation of *Campoletis chlorideae* against *H. armigera* infesting chickpea

During December 2006- January 2007, 100 females of *C. chlorideae* were released on chickpea (cv. ICCV-03206). In the treatment plots, 22.2% of the larvae were parasitised whereas only 0.1% were parasitised in control plot. At the end of 4 releases, the pod damage was 13.3% and 17.9%, respectively.

(b) Life-table studies on *Orius tantillus* on *Corcyra cephalonica* and *Sitotroga cerealella*

Life- table studies on *O. tantillus* reared on *C. cephalonica* and *S. cerealella* indicated that there was not much difference in the approximate duration of a generation (T_c) and net generation time (T) (Table1). The reproductive rate (R_0), finite rate of increase (λ), hypothetical F_2 ♀S and weekly multiplication rate of the predator were higher when reared on *Sitotroga* than on *Corcyra*. It was

Table 1. Fertility parameters of *Orius tantillus* when reared on two hosts

Reared on	R_0	T_c	r_c	r_m	T	λ	Doubling time (days)	Hypo. F_2 ♀S	WMR
Corcyra	1.31	30.42	0.009	0.010	27.01	1.02	33.4	1.72	1.15
Sitotroga	9.97	31.37	0.073	0.079	29.00	1.18	4.12	99.40	3.25

WMR: Weekly multiplication rate

evident that *O. tantillus* could be mass-produced efficiently on UV-irradiated eggs of *S. cerealella.*

(c) Life-table studies on *Orius tantillus* at different temperatures

Similar studies on *O. tantillus* at different temperatures revealed that the net reproductive rate (R_0) was higher at 24, 28 and 32°C in comparison to 20°C. The approximate rate of increase (r_c), precise intrinsic rate of increase (r_m), finite rate of increase (λ), and weekly multiplication rate were higher at 32°C. Hypothetical F_2 females were highest at 28 °C and at this temperatures reproductive rate, intrinsic rate of increase and weekly multiplication rate were also reasonably high. The doubling time was around 4 days at 28 °C, while at 32 °C, it was 3 days (Table 2.).

(d) Biology and feeding potential of *Xylocoris flavipes*

The warehouse pirate bug, *Xylocoris flavipes* could be successfully multiplied on *Corcyra cephalonica* eggs. The nymphal stage lasted 17 to 21 days (mean 19 days). One nymph could feed on a mean of 3.4 eggs and an adult 10.3 eggs per day. The adult male lived for 7 to 14 days (mean 10.8 days) and female for 21 to 38 days (mean 28 days). The mean egg laying per day was 1.68 and total egg laying was 61.96. The day-wise feeding potential of nymph and adult and the day-wise fecundity are depicted in Figs 5 and 6.

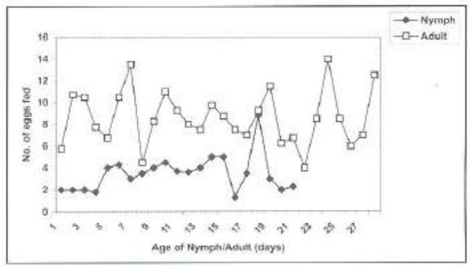

Fig 5. Day-wise feeding potential of nymph and adult of *Xylocoris flavipes*

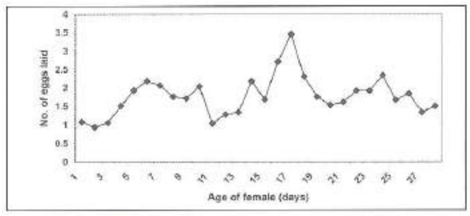

Fig 6. Day-wise fecundity of *Xylocoris flavipes*

Table 2. Fertility table of *Orius tantillus* when reared at different temperatures

Rearing temperature °C	R_0	T_c	r_c	r_m	T	λ	Doubling time (days)	Hypo. F_2 ♀S	WMR
20	8.24	60.72	0.034	0.030	71.01	1.083	8.70	67.90	1.73
24	10.94	35.93	0.067	0.056	43.03	1.167	4.51	119.68	2.93
28	11.42	32.74	0.074	0.070	35.04	1.187	4.04	130.42	3.32
32	10.5	21.82	0.108	0.117	20.03	1.281	2.80	110.25	5.65

Table 3. Fertility parameters of *Blaptostethus pallescens* when reared on two hosts									
Reared on	R_0	T_c	r_c	r_m	T	λ	Doubling time (days)	Hypo. F_2♀S	WMR
Corcyra	39.5	33.58	0.11	0.07	53.01	1.287	2.57	1560.25	5.85
Sitotroga	19.79	35.49	0.08	0.04	68.01	1.214	3.57	391.64	3.89

(e) Life table studies on *Blaptostethus pallescens* on eggs of two host insects

The life table studies of *B. pallescens* indicated that the net reproductive rate (R_0), hypothetical F_2 females and weekly multiplication rate were higher when *B. pallescens* was reared on *C. cephalonica* in comparison to the corresponding values when reared on *S. cerealella* (Table 3), indicating that *B. pallescens* can be multiplied successfully on *C. cephalonica* eggs.

(f) Life table studies on *Blaptostethus pallescens* at different temperatures

The life table studies on *B. pallescens* at four constant temperatures revealed that the reproductive rate (R_0) was highest at 28°C followed by 20°C (Table 4). Finite rate of increase (λ) and rate of increase (r_c and r_m) values were higher at 24 and 28°C. However, the hypothetical F_2 females and weekly multiplication rate were higher at 28°C in comparison to the corresponding figures at 24°C. The experiment indicates that *B. pallescens* can be multiplied efficiently by rearing them at a constant temperature of 28°C.

(g) Evaluation of *Blaptostethus pallescens* against red spider mite

The anthocorid predator *B. pallescens* nymphs fed on an average 12.2 mites per day with a total feeding of 255, whereas the adult fed on 6 mites per day with a total feeding of 105 (Fig. 7 and 8). When fed on mites in confined conditions, the longevity of adult was only 19 days, whereas when fed on *Corcyra* eggs, the adults could live even up to 2 months. In net house the mite population was 330.5 per leaf on control plant whereas it was only 74.1 mite per leaf on treatment plant.

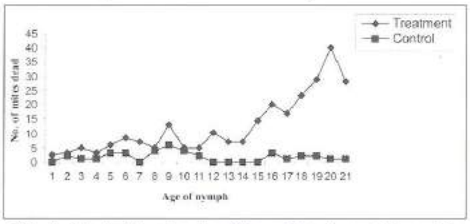

Fig 7. Mortality of red spider mites in containers in laboratory studies with and without *Blaptostethus pallescens* nymph

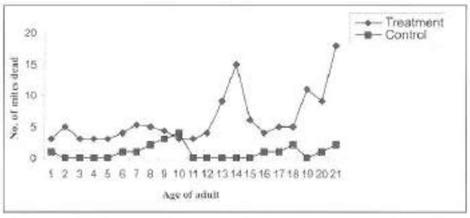

Fig 8. Mortality of red spider mites in containers in laboratory studies with and without *Blaptostethus pallescens* adult

Table 4. Fertility table of *Blaptostethus pallescens* when reared at different temperatures									
Rearing temp	R_0	T_c	r_c	r_m	T	λ	Doubling time (days)	Hypo. F_2♀S	WMR
20°C	48.91	85.57	0.04	0.04	97.00	1.110	6.62	2392.19	2.08
24°C	41.39	44.55	0.08	0.06	59.00	1.212	3.60	1713.13	3.80
28°C	65.05	48.99	0.08	0.05	74.00	1.217	3.53	4231.50	4.02
32°C	11.26	38.70	0.06	0.04	52.00	1.155	4.82	126.79	2.71

(h) Evaluation of *Orius tantillus* against thrips

The mean feeding potential of nymph, adult male and adult female of *O. tantillus* on *Scirtothrips dorsalis* was 3.1, 4.8 and 5.1, respectively with a total feeding of 42, 105 and 211, respectively. *Orius tantillus* was released @150 nymphs/ 15 sq.m. on rose infested with *S. dorsalis*. There was a reduction in infested buds/flowers from 79.3% to 18.08% in the first trial and 96.5 to 48.1% in the second trial.

(v) Development of novel method of mass production of *Cryptolaemus montrouzieri* on eggs of *Sitotroga cerealella* and its storage and packing techniques

(a) Biology of *S. cerealella* on different grain media

Biology of *S. cerealella* was studied using paddy, unhusked wheat, barley and maize as food. Biological parameters indicated that irrespective of the grains used for rearing, the egg, larval and pupal period ranged between 5.12-8.10, 15.5-24.00, 7.22-10.9 days, respectively. Total average life cycle ranged from 37.8 to 39.0 days. Maximum average fecundity was obtained on maize (132.7 eggs/female) followed by paddy (120.1 egg/ female).

(b) Life table studies on *S. cerealella*

Life table studies were conducted at 25 and 30°C. Sex ratio was 1:1 at both the temperatures. Minimum developmental time occurred at 30°C for both sexes. Immature survivorship was higher at 25 °C, however, highest fecundity occurred at 30 °C.

(c) Mass multiplication of *S. cerealella* on unhusked wheat and identification of problems associated with continuous egg production

The oviposition period of *S. cerealella* lasted for four to five days but maximum oviposition i.e. 80-90% of total eggs were in first three days. Total egg production during the year was 115.5 cc with average egg production on alternate day being 1.28 cc and average production per month was 19.25 cc.

(d) Rearing of *C. montrouzieri* on *S. cerealella* eggs

Eggs of *S. cerealella* exposed to UV rays were provided to a day old *C. montrouzieri* larvae. Results of these generations indicated that pupation was 66.1% and adult emergence from these pupae was 83.2%. Average larval and pupal periods were 14.9 and 7.0 days, respectively whereas adult longevity was 42.2 days. Average adult weight was 8.0 mg while female percentage was 39.6%.

(e) Comparison of production of *C. montrouzieri* when reared on mealybugs and *S. cerealella* eggs

The larval and pupal mortality of *Cryptolaemus* was 26-32 and 15-18 %, respectively when reared on *S. cerealella* eggs . The corresponding values when reared on mealybugs were 15-19 and 10-12 %. With initial culture of 100 larvae, we are likely to get 58-61 beetles when reared on *S. cerealella* eggs and 73-75 beetles on mealybugs as host.

(f) Use of plastic louvers for rearing *C. montrouzieri* larvae

Plastic louver (60 x 22 cm) with 2.5 cm cubical cells were found suitable for rearing *C. montrouzieri*. A quantity of 2,500 cc of *S. cerealella* eggs and 44 plastic louvers will be required to produce 5,000 adults of *C. montrouzieri*.

(vi) Studies on the natural enemies of *Ceratovacuna lanigera*

(a) Distribution of *Dipha aphidivora*, *Micromus igorotus* and *Encarsia flavoscutellum* in sugarcane

The distribution of *D. aphidivora, M. igorotus* and *E. flavoscutellum* in sugarcane fields with infestation of the woolly aphid, *C. lanigera*, was studied in Mandya and Shimoga districts. The parasitoids were observed in only 4 of the 20 fields surveyed in Mandya and Shimoga districts, while the predators, *D. aphidivora* and *M. igorotus* were present in all the fields. The pest population was generally very low in all the areas surveyed. Surveys near Mandya revealed the presence of all the three natural enemies in fields in Pandavapur taluk, while the pest itself was absent in most fields in Mandya taluk. Syrphids (*Eupeodus confrater*) were also observed in some fields in Kathalagere farm, Shimoga district. The pest population was very low in all the areas surveyed and hence the distribution patterns of the pest and its natural enemies could not be studied.

(b) Distinguishing unparasitised from *Encarsia*-parasitised hosts

The only morphological change that was observed was a dark patch with less woolly covering near the caudal end possibly indicating that the aphid was parasitised by *E. flavoscutellum*. It was seen that from 70 % of such suspected aphid hosts the parasitoids emerged. A cage was developed to study the development of the aphid and parasitoid in the laboratory.

(c) DNA markers for detection of the species involved in the interaction

DNA was isolated following the usual procedure from *D. aphidivora*, *M. igorotus*, *E. flavoscutellum* and *C. lanigera* for further amplification of the ITS-1 region and electrophoresis to enable identifying the DNA from each of them. The DNA isolated from the four species did not yield clear results for the four species except for *E. flavoscutellum*, which had about 700 bp.

(d) Host-range and life table studies on *Micromus igorotus*

In addition to 12 species of aphids evaluated earlier, *M. igorotus* larvae could feed on *Aphis nerii* but failed to develop on *A. pisum* indicating preference to aphids belonging to Aphidini tribe than to Macrosiphini. Percentage pupation and adult emergence were highest when reared on *Pseudoregma bambusicola*. When reared on *Aphis craccivora* supplemented with protinex and water, highest longevity of 44 days and fecundity of 1135 eggs/female were recorded.

(e) Studies on larval rearing units for *Micromus igorotus*

Maximum (95%) pupae of *M. igorotus* were formed in sugarcane leaf fold in the midrib when reared on *C. lanigera*. Out of different materials viz., gauze swab, human hair, cotton swab and threads, maximum eggs were obtained on cotton threads. It was found that 26.5 % more eggs were laid on vertically placed poly cotton threads, as compared to that placed horizontally. Woollen threads received 4.2 times more eggs than sewing threads.

(vii) Screening of trichogrammatids against *Sesamia inferens*

Out of the 12 species tested, highest parasitism of *S. inferens* eggs was by *T. japonicum* and *T. brassicae* (73.5%), which was at par with *T. chilonis* (67.2%) but significantly more than all other species tested (Table 5.). The developmental period ranged from 10.0 – 13.0 days and percent emergence varied from 24.8 – 43.7% across the twelve species. The percent females besides two

Table 5. Screening of various trichogrammatids against *Sesamia inferens*

Species	Parasitisation (%)	Developmental period (days)	Emergence (%)	Females (%)
Tr. armigera	16.2	12.0	38.7	78.0
Tr. bactrae	40.1	10.0	29.9	70.3
T. achaeae	32.6	12.0	28.5	83.8
T. brasiliense	52.9	11.2	40.3	100.0
T. brassicae	73.5	10.0	33.3	39.4
T. chilonis	67.2	11.8	43.7	54.3
T. dendrolimi	0.0	0.0	0.0	0.0
T. embryophagum	2.4	13.0	100.0	100.0
T. evanescens	48.1	11.0	43.0	73.8
T. japonicum	73.5	12.5	34.3	72.1
T. mwanzai	29.5	11.0	24.8	77.7
T. pretiosum	56.2	11.0	35.9	37.9
SEM ±	2.87	0.23	4.8	5.23
CD at 5%	5.88	NS	7.2	6.98

thelytokus species, ranged from 37.9% in *T. pretiosum* to 83.8% in *T. achaeae*.

(viii) Herbivore-induced plant synomones and their utilization in enhancement of the efficacy of natural enemies

The adults of *T. chilonis* conditioned to cues from cotton leaf volatiles recorded higher percentage parasitism (55.4 %) in comparison to unconditioned (39.6 %).

Seven-day-old nymphs of *B. pallescens* fed on 90% of *H. armigera* eggs placed on washed chickpea leaves (free from maleic acid and ketones) but only on 60% of eggs placed on unwashed leaves confirming that the maleic acid and ketones released by glandular hairs have negative impact on *B. pallescens* predation.

The major profile of rose green leaf volatiles includes 13 fractions, and three compounds *i.e.* Ethyle phthalate, Pentadecane and Hexadecane constituted 9.5, 8.0 and 6.8 % of total volatiles present. Similarly, the volatile compounds identified from okra leaves, mainly comprised of plant hydrocarbons, and the main constituents were - phthalic acid (37.3%), pentadecane (18.0%) and hexadecane (13.3%). In the volatile profile of these two species nothing was found having negative interaction with the *B. pallescens*.

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

The ovipositional response of *C. carnea* was studied in oviposition cages with various combinations of caryophyllene, μ pinene and linalool at different combinations. The combination of caryophyllene μ pinene and linalool at 01:01:01 recorded the highest oviposition (26.1 eggs) followed by caryophyllene, μ pinene and linalool 0.1 : 01. 0.2% (14.1).

Caryophyllene oxide at 0.1% recorded the highest parasitisation by *T. chilonis* (46.3%) and least parasitisation was recorded by myrcene at all concentrations.

Highest oviposition of 42.1% eggs by *C. carnea* was recorded on the cotton plants exposed to methyl salicylate for 24 h as against 7.4 eggs on unexposed plants.

(x) Development and evaluation of improved strains of biocontrol agents

(a) Development of low temperature and pesticide-tolerant strain of *Chrysoperla carnea*

Studies have been initiated to select artificially *C. carnea* for tolerance to insecticides. The mortality of larvae of *C. carnea* treated with 0.0025% monocrotophos topically and reared on *C. cephalonica* eggs varied from 20 - 25% with 90% adult emergence. The mortality in imidacloprid 0.0005% treatment varied from 5 - 25% with 95% adult emergence.

(b) Studies on quality attributes of different populations of *C. carnea*

Chrysoperla carnea was collected from cotton fields in Punjab and Nagpur and are maintained on *C. cephalonica* eggs continuously for various experiments. During the survey, *Mallada boninensis* from cotton fields in Aurangabad, Nagpur, Salem and *Apertochrysa* sp. from cotton fields in Raichur and Dharwad were also recorded.

Freshly hatched larvae of *C. carnea* collected from Nagpur, Delhi (Lab) and Punjab were reared on *C. cephalonica* eggs individually for three generations and all the quality attributes of these populations were recorded. The survival of these populations ranged from 85.0 to 87.4 %. Maximum cocoon weight was recorded for Nagpur (10 mg) followed by Delhi, Punjab and PDBC (all 9 mg). Highest longevity was recorded for Nagpur (60 days) and Delhi (60 days) followed by Punjab (46 days) and PDBC (46 days). Highest fecundity was recorded on *C. carnea* collected from Nagpur (411 eggs/female) followed by Delhi (353), PDBC (338) and Punjab (264) populations.

(c) Tolerance in different populations of *C. carnea* against pesticides

There was no oral toxicity to 2-3-day-old larvae of *C. carnea* collected from Punjab, Delhi and PDBC when fed with *C. cephalonica* eggs treated with acephate (0.67 g/l), metasystox (2 ml/li), karate (0.6 ml/l), success (1.2 ml/l) and imidacloprid (0.5 ml/l).

Pesticides were evenly sprayed on cotton leaves on which *Corcyra* eggs were provided as food to the larvae of *C. carnea*. Imidacloprid and Acephate caused 20 % mortality to three days old larvae of *C. carnea* collected from Nagpur. Three days old larvae of *C. carnea* collected from Punjab and Coimbatore could withstand metasystox (2 ml/l), karate (0.6 ml/l) and success (1.2 ml/l) treatment.

(d) Tolerance in different populations of *C. carnea* to high temperature

Freshly emerged *C. carnea* collected from Delhi, Punjab and Bangalore were exposed to variable temperature (32-38 °C). The population from Punjab completed the larval period in 8.5 days, which was less than that of Delhi and Bangalore populations. Pupal period of Punjab and Delhi population was 6 and 6.7 days, respectively, which was shorter than that of Bangalore populations. Maximum pupal weight was recorded from Delhi population followed by Punjab and Bangalore (Table 6). The longevity of *C. carnea* from Delhi and Punjab was 75 and 74 days, respectively and the same for Bangalore was 60 days. Fecundity of the predator from different locations varied from 38 days to 121 days and maximum was in Punjab followed by Delhi and Bangalore (Fig. 9). Longevity of these populations varied from 34 to 36 days.

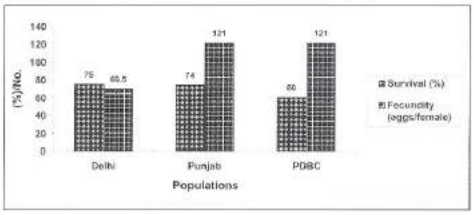

Fig. 9. Tolerance level of different populations of *Chrysoperla carnea* to high temperature (32-38 °C)

(e) Tolerance in different populations of *C. montrouzieri* against pesticides

Cryptolaemus montrouzieri populations from Bangalore, Coimbatore, Delhi and Shimoga were able to withstand imidacloprid with a mortality range of 0 - 40 %. On the other hand, quinalphos caused 100 % mortality in all the populations.

(f) Evaluation biological attributes of *Goniozus nephantidis*

The biological parameters of two the populations of *Goniozus nephantidis* were studied at 32 + 1°C and 26°C for over four generations. There was no marked difference in the various parameters between the populations (Table 7). However, enhanced attributes were observed at 32°C than at 26°C indicating that 32 °C is more congenial for development of the parasitoid irrespective of the population.

Table 6. Biological parameters of different populations of *Chrysoperla carnea* at variable temperature (32-38 °C)

Population	Larval duration (days)	Pupal duration (days)	Pupal weight (mg)	Longevity (days)
Delhi	9.0	6.0	10.0	36.0
Punjab	8.5	6.7	8.9	36.0
PDBC	10.2	8.0	8.0	34.0

Table 7. Biological attributes of *Goniozus nephantidis* at 32 °C and 26 °C

Biological attributes	Temperature			
	26 °C		32 °C	
	Bangalore	Kerala	Bangalore	Kerala
Mean no. of larvae parasitised	8.6	8.9	9.6	9.2
Mean no. of eggs/larva	12.6	11.9	14.6	14.2
Mean fecundity	108.2	112.4	136.3	142.8
Mean adult longevity (days)	43.3	45.2	56.2	53.6

The population from Kerala had higher fecundity, while the number of larvae parasitised and adult longevity were more in Bangalore population at 32°C.

(g) Evaluation of biological attributes of *Cotesia flavipes*

Population of *Cotesia flavipes*, an important parasitoid of several lepidopterous borers was collected from Shidalaghatta, Haveri, Chitradurga and Bangalore. The culture was maintained on *Chilo partellus* larvae reared on semi-synthetic diet. The biological attributes of the parasitoid was studied at 26 ± 1°C. Among these, the population from Shidalaghatta performed better with mean number of 20 cocoons /larvae as compared to others (15-17). The female progeny (72.5%) and the adult longevity (7.2 days) were also higher in the Shidalaghatta population (Table 8). Shidalaghatta population recorded higher parasitisation (23.1%) followed by Chitradurga (21.2%) and Bangalore (19.4%).

(xi) Molecular characterization of biocontrol agents

(a) Molecular characterization of trichogrammatids

DNA was extracted from several *Trichogramma* spp. using chelatin agent Chelex. Sequences generated were deposited with GenBank accession nos. *T. chilonis* (DQ 220703), *T. brassicae* (DQ314611), *T. mwanzai* (DQ381279), *T. evanescens* (DQ381280), *T. brasiliense* (DQ381281), *T. dendrolimi* (DQ344045), *T. embryophagum* (DQ344044), *T. japonicum* (DQ 471294) and *T. pretiosum* (DQ 525178). The size of the ITS-2 region varied from 1000 bp – 500 bp in the different *Trichogramma* species used in the studies (Fig. 10). Based on this size variation three distinct groups were formed (Fig. 10): Group I included *Trichogrammatoidea armigera*, *T. achaeae* and *Tr. bactrae*. The size of ITS-2 product varied from 700bp to 1000bp. Group II included *T. japonicum* and *T. embryophagum* and the size of ITS-2 product varied from 570 to 600bp. Group III included *T. chilonis*, *T. pretiosum*, *T. evanascens*, *T. mwanzai*, *T. brasiliense*, *T. dendrolimi and T. brassicae* and the size of ITS-2 pcr product in these seven species varied from 500 to 550bp. ITS-2 sequences of different species were deposited in GenBank. The dendrogram constructed based on ITS-2 sequences generally tallied with that of traditional taxonomy.

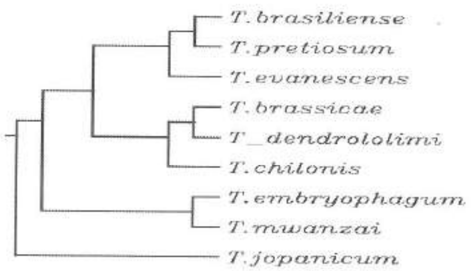

Fig. 10. Dendrogram based on sequencing data of nine species

(b) Studies on *Wolbachia*-infested trichogrammatids

Studies were carried out with three species, viz. *T. chilonis*, two thelytokus species *T. embryophagum* and *T. brasiliense*. Iso-female

Table 8. Biological attributes of different populations of *Cotesia flavipes*

Biological attributes*	Population			
	Shidalaghatta	Haveri	Chitradurga	Bangalore
Mean no. of eggs laid/female	19.6	18.8	19.4	19.1
Mean development time (days)	17.8	20.2	18.4	18.6
Mean Adult longevity (days)	7.2	6.8	6.9	6.9
Mean female progeny (%)	72.5	64.6	68.4	69.8
Mean parasitism (%)	23.1	18.6	21.2	19.4
No. of cocoons formed/larva	20.4	16.6	17.4	17.8

*Mean of 3 generations

lines were raised to get pure genetical lines. Total genomic DNA was isolated from 10 adults of each species. Among the three species only *T. brasiliense* gave *Wolbachia* band indicating presence to *Wolbachia* in it. However, other thelytokus species *T. embryophagum* DNA showed no presence of *Wolbachia*, thereby indicating that in this species thelytoky is governed genetically.

(c) Polyacrylamide gel electrophoresis (PAGE) of different *C. carnea* populations for esterase activity

Laboratory and field-collected (Punjab and Nagpur) larvae and adults of *C. carnea* were analysed for esterase activity through native PAGE. Non-denaturing PAGE of the homogenates of *C. carnea* from different populations stained for α-Napthyl acetate indicated difference in composition of esterase isozymes. Esterase bands were designated as E1-E4, indicating E1 as the slowest migrating esterase and E4 as the fastest. E1, E2, E3 and E4 were 4 separate bands observed in the Punjab larva, however the Punjab adult exhibited E1 and E2 band. Similarly E1, E2 and E3 bands stained in Nagpur adult. Bangalore adult and larva showed stained similar E1, E2 and E3 band. The intensity of the band is less in Bangalore larva and adult compared to Punjab and Nagpur adults. The difference in staining pattern or intensity may be related to individual isozyme activity to the substrate used or the genetic variation among different populations.

(d) Molecular characterisation of *C. carnea* and *C. montrouzieri*

Multiple sequence alignment of ITS-2 was performed to elucidate the phylogenetic relationship. ITS-2 regions of *C. montrouzieri* collected from Coimbatore, Delhi and Shimoga were amplified and the base pair is 500 bp. There was no significant difference in base pairs among these populations. Molecular characterization of *C. carnea* (538bp) was done and the DNA sequence was submitted to National Centre for Biotechnology Information, USA. GenBank Accession No. DQ825504. Molecular characterization of *C. carnea* (18-S RNA) collected from Delhi and *Mallada astur* (18-S RNA) from Bangalore was done.

(e) RAPD for distinguishing different geographical populations of the predators

RAPD assay involved genomic DNA of *C. carnea* collected from Punjab and Delhi using short primers CO7, C12, C14, C15, C16, C18, C19, KO1, KO2, K15 and K19 (9-10 bases). Differences in the patterns of DNA fragments amplified in populations of *C. carnea* were observed. Random primers C16, C19, KO2 and K19 produced polymorphic banding patterns, which can be used to distinguish the two populations of *C. carnea* collected from Punjab and Delhi.

(f) Characterization of ITS-2 region of the *G. nephantidis* populations

Molecular characterisation of the ITS-2 region of the populations of *G. nephantidis* was carried out to assess the variations, if any. DNA was eluted by MinElute Gel Extraction Kit (Qiagen) and sequencing was done. The size of the ITS-2 of both the populations was 800bp. The BLAST results revealed that ITS-2 region of the population from both the regions was 50% similar to ITS-2 region of *Diadegma rapei* (234/468 nucleotides).

(xii) Development of improved formulations of NPV for the management of *Helicoverpa armigera* and *Spodoptera litura* in tomato

(a) Evaluation of different adjuvants with *Helicoverpa armigera* NPV (*Hear*NPV)

*Hear*NPV along with different combinations of adjuvants were exposed to an irradiation of 500 W/m^2 for a period of 90 minutes in a suntest machine. All adjuvants screened significantly increased the larval mortality. However, the combinations, viz. molasses 5% + Tinopal 0.2% + lampblack 0.1%, molasses 5% + Tinopal 0.2%, molasses 5% + lampblack 0.1 % and crude sugar 5% + Tinopal 0.2% resulted in a larval mortality of 90-94 % with a relative efficacy of 1.8 over control. These treatments were on a par with non-irradiated virus. Tinopal 0.2% when used alone could result in a larval mortality of 84.5%.

(b) Evaluation of different adjuvants for increasing the persistence of *Hear*NPV against direct sunlight

A pot experiment on the effect of adjuvants on the persistence of *Hear*NPV on tomato revealed that 24 h after treatment, molasses 5% + Tinopal 0.2% + lampblack 0.1% was found significantly superior to all other treatments resulting in larval mortality of 80%. On day two, molasses 5% + Tinopal 0.2% + lampblack 0.1% and crude sugar 5%+ Tinopal 0.2% were superior to all other treatments resulting in 70 % mortality. This trend continued up to five days after treatment.

(c) Field efficacy of a wettable powder formulation of *Hear*NPV against *H. armigera* on tomato

In a field experiment on the efficacy of *Hear*NPV against *H. armigera* on tomato, addition of an adjuvant mix consisting of molasses, tinopal and lampblack enhanced the efficacy of a wettable powder formulation. Application of crude sugar (5.0%) and Robin blue (0.1%) to a commercial NPV formulation was also equally effective in reducing the pod borer damage and enhancing the grain yield (Table 9).

(d) Shelf-life studies of wettable powder formulation of *Hear*NPV

The shelf-life of *Hear*NPV formulations was studied both under room temperature and refrigerated conditions (3±2 °C). The LC_{50} values increased with increase in time. Under refrigerated conditions it was 0.0301 POB/mm^2 (zero month), which increased to 0.0378 POB/mm^2 on the ninth month for the formulated virus. In case of unformulated virus it was 0.0289 POB/mm^2 in the zero month which increased almost 1.5 times more by the end of ninth month. However, under refrigerated conditions all wettable powder formulations and unformulated virus showed no significant difference in the LC_{50} values for all the nine months. The unformulated virus under room temperature recorded significantly higher LC_{50} values from the seventh month onwards. The virus inactivation of the unformulated virus under room temperature was increased by 2.7 times by

Table 9. Field efficacy of *Hear*NPV against *Helicoverpa armigera*

Treatment	Controlled droplet applicator			Backpack hydraulic sprayer		
	Fruit damage (%)	Yield (t/ha)	C:B ratio (Rs/ha)	Fruit damage	Yield (t/ha)	C:B ratio (Rs/ha)
NPV wettable powder formulation + adjuvant*	4.6^a	67.3^a	1:3.4	4.4^a	70.4^a	1:3.6
NPV wettable powder formulation	6.7^b	58.7^b	1:2.9	6.3^b	61.1^b	1:3.0
NPV unformulated + adjuvant	4.0^a	69.2^a	1:3.6	4.4^a	70.6^a	1:3.7
NPV unformulated	6.5^b	60.4^b	1:3.0	6.0^b	62.4^b	1:3.1
Commercial NPV + adjuvant**	4.1^a	68.3^a	1:3.4	4.3^a	70.5^a	1:3.5
Monocrotophos (450 g a.i./ha)	4.5^a	70.5^a	1:3.8	4.4^a	71.6^a	1:3.9
Untreated control	21.7^c	51.5^c	1:2.6	22.5^c	52.7^c	1:2.7

*Molasses 5%+Tinopal 0.2% + lampblack 0.1%

**Crude sugar 5%+ Robinblue 0.1%

Means followed by the same letter in a column are not significantly different (P=0.05)

the end of ninth month. The wettable powder formulation packed with nitrogen under vacuum showed no significant difference in the LC_{50} values during all the nine months of storage under room temperature. By the end of nine months (under room temperature) the LC_{50} value of unformulated virus suspension was 2.1 times more than wettable powder formulation packed with nitrogen under vacuum. It also recorded least LC_{50} values in all the nine months under both temperature conditions.

(e) Evaluation of different adjuvants for increasing the persistence of *Splt*NPV against direct sunlight

Results of a pot culture experiment showed that a combination of molasses 5.0%, Tinopal 0.2% and lampblack 0.1% as adjuvant reduced the inactivation of *Splt*NPV significantly. On all the days of the observation, the adjuvant mix recorded significantly a higher percentage of original activity (Table 10). The individual adjuvants were not as effective as their combination in protecting the virus from the inactivation by the sunlight.

(f) Evaluation of adjuvants for UV protection of *Amsacta albistriga* NPV (*Amal*NPV).

AmalNPV along with different adjuvants were irradiated at 500W/m^2 for 90 minutes in a sun test machine. The virus samples were bioassayed against third and fourth instar host larvae. In case of third instar larvae, crude sugar 5% and Tinopal 0.2% when used as adjuvants resulted in a larval mortality of ranging from 93-95% indicating a high level of persistence of virus. Similar results were obtained in fourth instar larvae where the relative efficacy was 1.9 and 1.8 for crude sugar 5% and Tinopal 0.2% respectively (Table 11).

Table 10. Efficacy of different combination of *Splt*NPV + adjuvants in increasing the persistence ofvirus on tomato

Treatment	Mean per cent larval mortality after days of exposure		
	1	3	5
Molasses 5% + Tinopal 0.2% + lampblack 0.1%	88.6^a (96.1)	65.3^a (70.9)	43.5^a (47.2)
Tinopal 0.2%	81.9^b (90.2)	50.1^b (55.2)	32.3^b (35.6)
Molasses 5%	76.2^c (83.5)	49.2^b (53.9)	28.9^c (31.6)
Lampblack 0.1%	76.2^c (83.5)	47.3^b (51.8)	28.5^c (31.2)
Virus alone	71.3^d (83.1)	38.2^c (44.5)	18.9^d (22.0)

Figures in parentheses represent per cent original activity remaining
Means followed by the same letter in a column are not significantly different (P=0.05)

Table 11. Evaluation of adjuvants for UV protection against *Amal*NPV using suntest machine

Treatment	3rd instar		4th instar	
	Larval mortality (%)	Relative efficacy	Larval mortality (%)	Relative efficacy
Crude sugar 5%	95.3^a	1.8	85.4^a	1.9
Molasses 5%	82.5^b	1.6	78.6^b	1.7
Tinopal 0.2%	93.2^a	1.8	83.2^a	1.8
Starch 1%	66.5^c	1.3	54.5^c	1.2
Soyaflour 1%	68.5^c	1.3	45.5^d	1.0
Irradiated virus	52.3^d	1.0	44.9^d	1.0
Non-irradiated virus	97.8^a	1.9	86.3^a	1.9

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

(xiii) Identification of pathogens of phytophagous mites and assessment of their potential in microbial control

(a) Growth studies on different isolates of *Hirsutella thompsonii* var. *synnematosa*

Out of the six isolates of *H. thompsonii* var. *synnematosa*, the maximum growth of 47.17 mm with a growth rate of 1.37 mm/day was observed in MF(Ag)31 while MF(Ag)32 recorded the minimum growth and growth rate of 42.67 mm and 1.22 mm/day, respectively, at the end of 30 days of incubation. The isolates cultured from white portion did not exhibit major differences in radial growth throughout the incubation period.

In the grey portion-derived cultures, the share of the white portion was found to be consistently more than the grey portion in the colonies of five isolates. The cultures significantly differed in the proportion of white and grey portions. Only one isolate, i.e. MF(Ag)28 showed more of grey portion (32.83 mm) than the white portion (10.17 mm). In the white portion-derived cultures also, the share of the white portion was found to be consistently more than the grey portion in the colonies of five isolates. The cultures significantly differed in the proportion of white and grey portions.

The number of conidia of *H. thompsonii* var. *synnematosa* at the three diameters in all the six isolates was significantly different from each other in both grey and white portion-derived cultures. The conidia of *H. thompsonii* var. *synnematosa* from grey portion-originated cultures showed more than 15% germination at the end of 1 h incubation. The isolate MF(Ag)27 was the best in terms of germination of conidia harvested from all the three diameters of the colony at the end of 2 h of incubation.

In general, there were no major differences in the micromorphology. However, all the isolates of *H. thompsonii* var. *synnematosa* derived from grey as well as white portions differed in terms of synnemata characteristics. The isolate MF(Ag)29 yielded the maximum number of mature synnemata.

(b) Effect of *H. thompsonii* metabolites on *Tetranychus urticae* nymphs

Tetranychus urticae nymphs treated with *H. thompsonii* metabolites showed very significant mortality (64.4%), which was 8.3 times more than the control mortality (Table 12). Significant differences in mortality were observed on all the days. However, very highly significant nymphal mortality was noticed on the third day of incubation.

(c) Effect of *H. thompsonii* metabolites on the fecundity of *T. urticae*

An adult female feeding on metabolite-treated leaf could lay only 22.40 eggs compared with 51.63 eggs laid by the mite feeding on untreated leaf over a period of 7 days (Fig. 11). A very highly significant reduction in egg laying of *T. urticae* was noticed from the second day onwards owing to metabolite treatment.

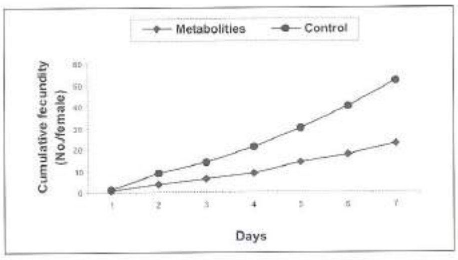

Fig. 11. Effect of *H. thompsonii* metabolities on the fecundity of *T. urticae*

Table 12. Effect of *Hirsutella thompsonii* metabolites on *Tetranychus urticae* nymphs

Treatment	Cumulative mortality (% ± SEM) after treatment (days)			
	1	2	3	4
Metabolites	21.1 ± 7.29 (26.4 ± 5.76)	40.0 ± 6.94 (39.1 ± 4.15)	48.9 ± 4.84 (44.4 ± 3.50)	64.4 ± 5.88 (53.5 ± 3.52)
Control	0.0 ± 0.00 (0.0 ± 0.00)	1.1 ± 1.11 (3.5 ± 3.50)	1.1 ± 1.11 (3.5 ± 3.50)	7.8 ± 2.22 (15.8 ± 2.64)
't' value	4.59*	6.55**	9.12***	8.58**

Note: Figures in parentheses are arcsine-transformed values

*Significant ($P = 0.05$); **highly significant; ***Very highly significant ($P = 0.001$)

(d) Effect of different entomopathogenic fungi in combination with adjuvants on *T. urticae* on okra in the greenhouse

Beauveria bassiana, *H. thompsonii*, *Lecanicillium psalliotae* and *Metarhizium anisopliae* in combination with two adjuvants, viz. cold-water dispersible starch (0.2%) and glycerol (1%) decreased the population of *T. urticae* on okra under greenhouse conditions. All the test fungi decreased the population of live mites (Table 13). There was a gradual decrease in the mite population over time, the maximum reduction being on the 10th day of observation. *H. thompsonii* was the best among the fungi with 51.8 and 75.6 % reduction in *T. urticae* population in comparison with the controls having adjuvants and no adjuvants, respectively. Ten days post treatment, *H. thompsonii* decreased the pre-treatment mite population by 85.2%.

(e) Development of new formulations of *H. thompsonii*

A new variant of the already available powder formulation ('Mycohit') was developed for multilocation field trials against the coconut eriophyid mite during 2006-07. The major difference being the active ingredient which in this case was the MF(Ag)66 isolate of *H. thompsonii* from Kerala. Also, the new formulation contains only mycelia of the fungus. This powder formulation, when tank-mixed separately with the three selected adjuvant, formed three new formulations.

(f) Field evaluation of *H. thompsonii* against the coconut mite

A field trial was laid out at Huskuru for evaluating the Kerala isolate [MF(Ag)66] of *H. thompsoniii* (mycelial formulation) in combination with the three selected adjuvants against the coconut mite. *Hirsutella thompsonii* in combination with the three adjuvants, viz. glycerol, yeast extract powder and malt extract broth (MEB) significantly reduced the post-treatment population of the coconut mite on the nut surface of samples collected from the tagged bunches 1 & 2 (Table 14). The fungus was able to cause disease in the mite on all the sprayed trees as evidenced during the post-treatment sampling. The maximum reduction of 97.23% in post-treatment population of the coconut mite was brought about by the fungus in combination with MEB. At pre-harvest stage, the damage score will be recorded for drawing valid conclusions.

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

(a) Glucanase production in *Trichoderma viride*

Twenty isolates of *Trichoderma* were tested for glucan utilization in broth cultures with carboxy

Table 13. Effect of different entomopathogenic fungi in combination with adjuvants on *Tetranychus urticae* on okra in the greenhouse

Treatment	No. of live mites/20-mm diameter of the lower leaf surface					
	Pre-treatment	Post-treatment (DAS)				
		2	4	6	8	10
*B. bassiana**	36.6	10.4	8.8	8.1	7.9	7.5
*H. thompsonii**	37.7	8.2	7.9	7.3	6.0	5.6
*L. psalliotae**	36.6	8.0	8.0	7.6	7.2	7.1
*M. anisopliae**	34.3	7.9	7.6	7.3	7.2	6.8
Control 1[@]	30.9	13.4	12.3	12.4	12.3	11.6
Control 2[#]	33.2	28.2	25.5	29.9	26.3	22.9
CD (0.05)	NS	3.2	2.1	3.65	2.30	2.69

*10^7 conidia/ml of 0.2% Tween 80 water + 1% glycerol + 0.2% cold-water dispersible starch

[@]0.2% Tween 80+0.2% cold-water dispersible starch+1% glycerol

[#]0.2% Tween 80

DAS: Days after spraying

Table 14: Field evaluation of new formulations of *Hirsutella thompsonii* against *Aceria guerreronis* on coconut at Huskuru, Bangalore Rural district, Karnataka

Treatment	Live mites (no./mm²)					
	Pre-treatment			Post-treatment		
	4th bunch	5th bunch	Mean	Tagged bunch 1 (2nd bunch)	Tagged bunch 2 (3rd bunch)	Mean
H. thompsonii (1%) + adjuvant 1 (0.5%)	6.48	3.97	5.22	0.71ᵃ	0.96ᵃ	0.84ᵃ(92.5)
H. thompsonii (1%) + adjuvant 2 (0.5%)	7.73	6.65	7.19	1.18ᵃ	2.04ᵃ	1.61ᵃ(85.6)
H. thompsonii (1%) + adjuvant 3 (0.5%)	11.91	4.64	8.27	0.11ᵃ	0.52ᵃ	0.31ᵃ(97.2)
Triazophos (Trifos 40) (0.2%)	9.40	3.46	6.43	0.56ᵃ	0.86ᵃ	0.71ᵃ(93.7)
Control	12.27	5.36	8.81	11.6ᵇ	10.76ᵇ	11.18ᵇ

Means followed by the same letter in a column are not significantly different (P=0.05)

Note: Figures in parentheses indicate per cent reduction over control.

methyl cellulose (CMC) and *Phytophthora* cell wall as sole carbon source. Isolates TV-4, TV-23, TV- 25, TV-29 and TV-30 showed good growth on CMC-amended medium with dry weights 73, 70, 65, and 61 (mg/ml). While the isolate TV-11 was poor in growth on CMC-amended medium with the mycelial dry weight of 29 mg/50ml of culture. The isolate TV-29 showed the maximum growth (113mg/50ml), followed by TV-25, TV-28 (both 61 mg/50ml), whereas the isolates TV-31 and TV-32 showed poor growth on PCWA medium, with a mycelial dry weight of 36 mg/50ml

Twenty isolates of *T. viride* were tested for their ability to produce glucanase in CMC-amended liquid medium and 9 isolates were tested for glucanase production in *Phytophtora* cell wall amended medium. In 1,4- glucanase assay, TV-32 exhibited high endo-1,4- glucanase activity in CMC-amended liquid medium. TV-32 had maximum absorbance (0.0405/ml) at 500nm, followed by TV-30 (0.0168/ml), TV-14 (0.0142/ml), TV-11 (0.0115/ml) and TV-31 (0.0103/ml). TV-30, TV-14, TV-11 and TV-31. The other isolates expressed less endo-1,4- glucanase activity in the extracellular fluid. This indicates the variability among the *T. viride* isolates to produce 1, 4 glucanase to utilize CMC. All the 20 isolates of *T. viride* were also tested for the β-1,3- glucanase production in the extracellular fluid with CMC as substrate and the activity was assayed calorimetrically. TV-13 (0.2199/ml) and TV-14 (0.1969/ml) recorded high absorbance at 500nm followed by TV-34 (0.1478/ml), TV-31 (0.1341/ml), TV-32 (0.1308/ml), TV-36 (0.1265/ml), TV-5v(0.1191/ml) and TV-30 (0.1054/ml). All the other isolates showed absorabance less than 0.1/ml.

Endo-1,4- glucanase production by seven isolates of *T. viride* using *Phytophthora* cell wall as the sole carbon source was estimated. The isolate TV-32 and TV-35 showed the highest activity (being 0.0392/ml and 0.0375/ml respectively), followed by TV-25 (0.0325/ml), TV-29 (0.0301/ml), TV-23 (0.0255/ml), TV-31 (0.0209/ml) and least value was observed for TV-28 (0.0190/ml). The isolate TV-32 secretes more amount of endo-1,4-glucanase enzyme in the extra cellular fluid when grown on PCWA liquid medium, followed by TV-34, TV-25,TV-29,TV-23, TV-31.

All the seven isolates were also tested for β-(1,3)-glucanase activity when grown in *Phytophtora* cell wall amended medium. Maximum absorbance was recorded in TV-34 (0.1939/ml), followed by TV-23 (0.1825/ml), TV-29 (0.1667/ml), TV-32 (0.1280/ml), TV-28 (0.1267/ml) and TV-25 (0.1079/ml).

In SDS-PAGE analysis it was observed that 71 kDa protein was secreted by several isolates of *T. viride* (5 isolates viz. TV-11, TV-25, TV-31, TV-32 and TV-36) that were grown on CMC-amended medium. Four isolates secreted 95 kDa (TV-25, TV-28, TV-31 and TV-32) and 68 kDa (TV-11, TV-30, TV-30 and TV-32) proteins. Three isolates each secreted 43 kDa (TV-11, TV-30 and TV-32) and 60kDa (TV-3, TV-28 and TV-30) proteins. The proteins of 110, 103, 89, 80, 78 and 29 kDa molecular weight were secreted by at least two isolates. A few proteins were secreted by only one isolate. They were 118 kDa (TV-11), 62 kDa (TV-28), 55kDa (TV-11), 50 kDa (TV-36) and 25 kDa (TV-36).

The SDS-PAGE analysis of extracellular proteins of selected *T. viride* isolates (TV23 and TV25) secreted in *Phytophthora* cell wall-amended medium showed that very few proteins were secreted in each. The isolates with good β 1, 3 glucanase activity and high protein content in colorimetric assays were selected for the PAGE analysis. TV23 secreted three proteins (122 kDa, 117 kDa and 115 kDa) while TV25 secreted a protein with high molecular weight (>200 kDa) along with 152 kDa and 122 kDa proteins. Both isolates produced the 122 kDa protein.

(b) Chitinase production in *T. virens*

Chitinase production and enzyme activity in 15 isolates of *T. virens* was studied. Chitinase production was very high in TVS-calicut, TVS-CPCRI and PDBC isolates TVS7, TVS9 and PDBC-12 (Fig. 12).

(c) Bioefficacy tests

When *T. virens* cultures were tested for their bioefficacy against *Fusarium ciceri*, soil application of talc formulation of isolates TVS1, TVS3 and TVS-Calicut showed maximum germination and root colonization besides root and shoot lengths. Though in all the plants treated with the isolates there was no symptom of wilt disease, based on germination and root colonization, TVS1 and TVS3 were found to be superior. TVS11 was found to be a poor colonizer and it did not promote the root and shoot growth (Table 15).

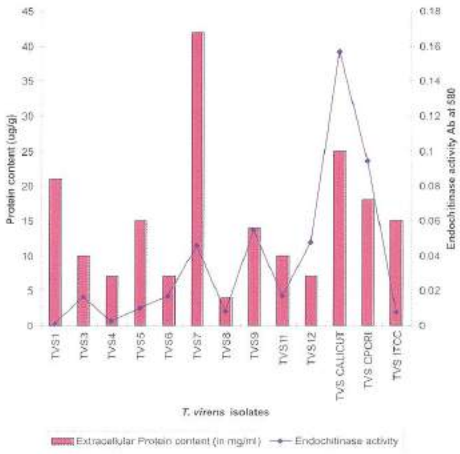

Fig. 12. Endochitinase activity and protein content in *Trichoderma virens* isolates grown on colloidal chitin-amended medium

(xv) Formulations of *Trichoderma* sp. and entomofungal pathogens with prolonged shelf-life and efficacy

(a) Effect of glycerol on the shelf-life of talc formulations of *T. harzianum*

There was no loss of moisture in talc formulations derived from media amended with 9% glycerol and packed in polypropylene bags, from the initial moisture content of 15.7%. In control and 3% glycerol-amended treatment, the moisture content came down to 10% by 6^{th} and 7^{th} months, respectively.

In formulations obtained from glycerol-amended media, sporulation could be observed during the drying of the formulation after mixing the biomass with talc. Addition of glycerol helped in getting more propagules at the time of packing. In control where there was no glycerol in production medium, from the initial population of 7.8×10^7, the viability got reduced to 9.0×10^4 after 5 months, that is below the CIB recommended level (2×10^6). In formulations obtained from glycerol-amended media, there was an increase in the viability during the storage at around 5^{th} month and that came down in subsequent months. The results indicate that storability of formulation obtained from media

Table 15. Effect of talc formulations of *Trichoderma virens* isolates in bioefficacy test against the wilt pathogen *Fusarium ciceri* on chickpea plants

T. virens isolate	Length (cm)		Root colonization (%)	Germination (%)	Disease incidence (%)
	Root	Shoot			
TVS1	10.69	22.29	80.0	93	Nil
TVS3	13.10	22.67	72.0	100	Nil
TVS5	22.67	12.78	25.1	100	Nil
TVS6	15.00	16.79	44.0	73	Nil
TVS7	13.80	22.70	64.0	93	Nil
TVS8	15.13	22.20	36.0	100	Nil
TVS9	13.53	20.60	64.0	100	Nil
TVS11	6.55	10.55	13.0	53	Nil
TVS Calicut	14.66	18.60	92.0	86	Nil
Fusarium ciceri alone	7.26	12.10	-	63	46.66$
Control	5.80	10.20	-	53	13.00

$ 13.3% dead, 30.0% showing wilt symptoms

without glycerol is 5 months only while addition of glycerol at 9% extends it by another 3 months while addition at 3 or 6% extends it by more than 3 months.

(b) Effect of heat shock at the end of fermentation on the shelf-life of *T. harzianum*

The moisture content in the *T. harzianum* formulations derived after heat shock treatment (40°C for 30 min or 40°C for 60 min at the end of log phase of the fermentation 72 h) gradually reduced to 10% from the initial moisture content of 15% by the 7th month. However, the water activity followed different pattern compared to moisture content. There was initial decrease (0.96, 0.95 0.93 in control, heat shock for 30 and 60 min) respectively in the water activity after 2 months and then it increased to 0.98 by the 4th month. After 6 months, there was a sudden reduction in the water activity to 0.86 in all the treatments.

The viability of propagules exposed to heat shock was increasing till 4th month and there was faster decline in the treatment that received heat shock at 30°C for 60 min after 5th month. In heat shock for 30 min also, there was decline but by the end of 6th month it was 9.68×10^8 compared to 5.2×10^7 in the treatment with 60 min shock. After the 6th month, the water activity in these formulations came down drastically to 0.86 and the CFU/g suddenly came down to less than 10^5.

(c) Effect of moisture content in the formulation on shelf-life of *T. harzianum*

In fermentor-grown *T. harzianum* formulations packed in aluminium foil covers with 20% moisture content, the water activity was near to saturation (i.e. 1.00) and it was maintained for two months. It reached 0.945 by 5th month end and by this time the viability also came down to 10^6 level. In formulations packed at 15% moisture content, the water activity came down from initial value of 0.964 to 0.95 after 5 months preceded by a increase during 2nd month of storage. The moisture content did not change significantly during the storage period. The higher moisture content (i.e. 15 or 20%) helped in retaining viability of propagules for comparatively longer time (2 months more) than that of formulations with 8 or 10% initial moisture content. However in all the formulations when the a^w got reduced, the viability also reduced drastically. This indicates that formulations made of biomass from liquid fermentation need to be stored at high water activity of 0.99 to 0.96.

(d) Shelf-life of *T. harzianum* in conidial formulations obtained from solid substrate fermentation with incorporation of substrate in formulation

Trichoderma harzianum was mass multiplied on ragi grain and mixed with talc powder at 1:9 ratio and stored for shelf-life studies. In normal and modified packing, the water activity did not change till the 5th month and afterwards it started coming down from 0.6 to 0.3. In these two packings, the initial moisture content was 0.75 and it did not differ significantly till 4th month. At the end of 8th month, the CFU/g were 1.3×10^9 and 9.2×10^7 in normal packing and in modified atmosphere packing, respectively. The initial propagules count was 1×10^{10} in these formulations. The population came down to 10^8 to 10^9 level after 2 months and the count did not differ significantly upto 8th month and the study is in progress. Variation in water activity or moisture content did not affect the CFU count significantly. The conidia obtained from solid substrate fermentation were tolerant to desiccation and dry conditions. They were packed at very low moisture content (<1%) and low water activity (<0.6). Under the same circumstances the formulations obtained from biomass of liquid fermentation were not able to retain viable propagules for more than a month.

(e) Shelf-life of *T. harzianum* in conidial formulations without incorporation of substrate

The water activity and moisture content in the talc formulations of *T. harzianum* were very low during the shelf-life though there was slight increase during 2nd month of shelf-life followed by decrease to water activity of 0.3 by 5th month. However, this reduction of water activity did not affect the viability of propagules as in the formulations obtained from the liquid fermentation. When there was slight increase of water activity and moisture content during 2nd month, there was corresponding increase in viability formulations.

(f) Effect of heat shock on the shelf-life of two entomofungal pathogens

The heat shock treatment of fermentor biomass of *B. bassiana* and *M. anisopliae* at 35°C and 40°C for 30, 60 and 90 minutes resulted in very less CFU counts in the initial samples itself indicating an adverse effect of heat shock on *B. bassiana* and *M. anisopliae*. The CFU counts of heat-shock (40 °C) subjected formulations came down below the standard (1.2×10^6 to 8.4×10^6) after 30 days of storage (Tables 16 and 17). The shelf-life of heat shock (35 °C) subjected formulations have come down to 2-4 months compared to the 6 months of shelf-life in control samples.

(h) Biological control of *Alternaria* leaf blight of tomato

The antagonistic effect of 48 isolates of *Trichoderma* spp. and one isolate each of *Gliocladium deliquescens* and *Chaetomium globosum* was tested against *Alternaria solani* and *A. alternata*. Among these, *T. harzianum* (TH-7) isolate showed highest inhibition of *Alternaria solani* (72.8%) and *A. alternata* (65.8%), followed by *T. pseudokoningii* (TP-1) isolate showing 69.4% inhibition of *A. solani* and

Table. 16. Effect of heat shock on the shelf-life of talc formulations of *Beauveria bassiana*

Treatment	CFU of *B. bassiana* on day						
	0	30	60	90	120	150	180
Heat shock at 40°C for 60 min	1.2×10^8	1.2×10^6	-	-	-	-	-
Heat shock at 40°C for 45 min	2.9×10^8	1.6×10^6	-	-	-	-	-
Heat shock at 40°C for 30 min	9.7×10^8	1.6×10^6	-	-	-	-	
Heat shock at 35°C for 60 min	128.0×10^8	69.3×10^8	10.6×10^8	2.7×10^8	-	-	-
Heat shock at 35°C for 45 min	176.0×10^8	102.0×10^8	20.6×10^8	12.1×10^8	1.2×10^8	1.2×10^6	-
Heat shock at 35°C for 30 min	203.0×10^8	137.0×10^8	41.6×10^8	17.2×10^8	2.4×10^8	3.9×10^6	-
Control (without heat shock)	694.0×10^8	463.0×10^8	197.0×10^8	104.0×10^8	83.0×10^8	24.2×10^8	3.2×10^8

Table. 17. Effect of heat shock on the shelf-life of talc formulations of *Metarhizium anisopliae*

Treatment	CFU of *M. anisopliae* on day						
	0	30	60	90	120	150	180
Heat shock at 40°C for 60 min	$4.3x10^8$	$4.8 x10^6$	-	-	-	-	-
Heat shock at 40°C for 45 min	$4.1x10^8$	$6.3x10^6$	-	-	-	-	-
Heat shock at 40°C for 30 min	$10.4 x10^8$	$8.4 x10^6$	-	-	-	-	-
Heat shock at 35°C for 60 min	$132.0 x10^8$	$73.0x10^8$	$1.8 x10^8$	$9.2x10^6$	-	-	-
Heat shock at 35°C for 45 min	$153.0 x10^8$	$102 x10^8$	$7.4 x10^8$	$23.8x10^6$	-	-	-
Heat shock at 35°C for 30 min	$192.0 x10^8$	$137.2 x10^8$	$16.2x10^8$	$17.2 x10^8$	$9.8x10^8$	$37.6x10^6$	-
Control (without heat shock)	$428.0x10^8$	$278.0 x10^8$	$198.0 x10^8$	$63.0 x10^8$	$16.8x10^8$	$34.9x10^8$	$1.4 x10^8$

65.8% inhibition of *A. alternata*. Other isolates like, *T.viride*- Tv-11, Tv-13, *T. harzianum*- TH-2 and TH-6 also showed 60-66% inhibition of *A. solani* and *A. alternata*.

Among the 24 isolates of phylloplane bacteria of tomato tested against *A. solani*, B-10, B-20, B-4, B-3, B-15 and B-14 isolates showed 40-50% inhibition of *A. solani*.

(xvi) Isolation, characterization and evaluation of indigenous *Bacillus thuringiensis* strains against lepidopterous pests

One hundred and fifty-eight isolates of *B. thuringiensis* were isolated from soil samples collected in Chattisgarh, Kerala, Western Ghats, Varanasi, etc. The isolates PDBC-BT1 and PDBC-BNGBT1 showed 100% mortality at three different dilutions against *Plutella xylostella* (cabbage leaf bioassay) and *Helicoverpa armigera* (diet bioassay). The isolate PDBC-BT1 was highly toxic to the first and third instars of *C. partellus*, even the lowest dilution (log 3.06 cfu/ml) giving 100% mortality.

SDS-PAGE analysis was done for the samples PDBC-BT1, BNGT1 and HD-1 with the standard molecular weight protein marker at 75 volts in 10% gel. All the samples contained proteins with molecular weights of 30, 25 and 17 kDa. A protein with 60-kDa molecular weight was observed in PDBC-BT1 and BNGT1, protein with 20-kDa molecular weight was obtained in PDBC-BT1 and HD-1. The HD-1 strain also showed 36 and 13 kDa protein bands, which were not found in other lines. BNGT1 was unique showing other bands corresponding to 60, 30, 25 and 17kDa. Agarose gel electrophoresis was done for samples PDBC-BT1, BNGT1 and HD-1 with standard molecular weight DNA marker. It was observed that the entire sample contains DNA of 7421 and 5804 bp.

(xvii) Isolation and characterization of plant growth-promoting endophytic bacteria and development of improved formulations

The endophytic bacteria maintained as PDBC culture collection include *Bacillus megaterium*, *B. circulans*, *Bacillus* sp., *Erwinia herbicola*, *Enterobacter agglomerans*, *Pseudomonas aeruginosa*, *Cryptococcus albidus*, *Pseudomonas fluorescens* (19), *P. putida* (1), *Pseudomonas* sp. (7), *Bacillus subtilis* (2), *B. megaterium* (phosphate solubilizer) and fluorescent pseudomonads (28). Assay for chitinase expression was done using colloidal chitin in media deprived of carbon source. *B. megaterium*, *B. circulans*, *Bacillus* sp., *P. fluorescens* and *B. subtilis* were tested and it was found that *Bacillus* sp. *P. fluorescens* and *B. subtilis* were positive for chitinase expression.

Antibiotic resistance pattern for plant endophytic bacteria was developed using octodisks (HiMedia) containing eight different antibiotics at different concentrations. Antibiotic resistance markers for *B. megaterium* and *Bacillus* sp. were developed. The selected markers were penicillin G (2 µg) and co-trimaxazole (25µg) for *B. megaterium* and penicillin G (2 µg), co-trimaxazole (25µg), cloaxcillin (5µg) and cefuroxime (30 µg) for *Bacillus* sp. The markers were used to reisolate the endophytic bacteria after seed treatment of chickpea

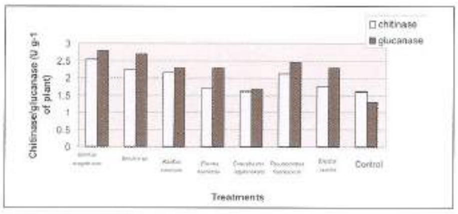

Fig. 13. Chitinase and ß-1,3 glucanase activities in endophytic and rhizospheric bacteria-treated plants after 18 days of germination

seeds. Out of the 25 root tissues tested, 10 tested positive for the presence of *B. megaterium* and 11 for *Bacillus* sp.

Chitinase activities were significantly higher in all bacteria-treated plants. The highest chitinase activity of 2.53 U/g of plant was observed in *B. megaterium*-treated plants (Fig. 13). *Bacillus* sp. also induced high ß-1,3-glucanase activity of 2.69 U/g.

The endophytic and rhizospheric isolates were screened for *in vitro* antagonism against the cotton pathogens *Fusarium vasinfectum, F. solani* and *Verticillium dahliae*. On tryptic soya agar (TSA), the highest inhibition of 50% was exhibited by the endophyte, *Bacillus* sp. and the lowest (25%) by *P. fluorescens* (rhizosphere isolate).

(xviii) Mass production, formulation and field-testing of entomopathogenic nematodes against important lepidopteran pests

(a) Interaction of EPN with soil types

Soil samples collected from various places were analysed and classified as per USDA textural classification. In the sandy clay loamy soil, *Steinernema carpocapsae* commenced infection and showed mortality of *Galleria* up to 20% at 18 h and 100% at 24 h at all dosages, on sandy clay loamy soil with 60% sand and 30% clay the reaction of *S. carpocapsae* has been the same, all doses induced mortality within 24 h – Similar results were obtained with *Heterorhabditis indica* also (Attur Farm). In Punjab soil the infection of *S. carpocapsae* was the fastest and all doses showed infection within 18 h and only the higher dose showed infection in Puducherry soil. *Heterorhabditis indica* was not very active in this type of soil where delayed infection was noticed after 36-48 h. Punjab soil was alkaline and Puducherry soil neutral in pH hence the differential rate of infection. Silty soil was not preferred by both nematode species when infection was delayed to 36-48 h. Clay soil of Thiruvananthapuram with about 40% each of sand and clay and rest silt was similar for both nematode species but more suited for *Steinernema* sp. than for *H. indica.*

(b) Formulation

Talc (T), China clay (CC), bentonite (B) and red China clay (RCC) were used for nematode formulation along with other adjuvants. The maximum survival of nematodes after three month storage was observed in T+CC; T+CC+B; T+RCC combinations and the survival ranged between 72-75%. After 120 days of storage, significantly low rate or no survival was observed in all combinations except T+CC and T+RCC where the survival was 52 & 55%. Viability of *S. carpocapsae* in the above formulations was significantly low compared to *H. indica*. Storage for 30 days greatly reduced the survival rate of *S. carpocapsae* and maximum survival observed was 75% in T+CC combination followed by RCC+CC and T+TiO^2 with 60& 55% respectively. Shelf-life of other formulations was below acceptable level during the same period and the results prove that this is not a feasible method for *S. carpocapsae*.

Heterorhabditis indica and *S. carpocapsae* infected cadavers incubated for 2 days were formulated by immersing in various aqueous suspensions and rolled in different inert materials for encasing the cadavers. In case of *H. indica* infected cadavers the maximum yield of 3.8 and 3.5 lakh IJs was observed when stored for 15 days and the progeny was reduced to 3.2 & 3.12; 2.85 & 2.12 and 2.43 & 1.98 lakh IJs /larva when checked at 30,45,60 days of storage for *H. indica* isolates PDBCEN 13.31 and PDBCEN 13.4, respectively (Table 18). *S. carpocapsae* infected cadavers when formulated could not retain IJs inside. Unprocessed CC-coated cadavers gave maximum yield of 2.75 lakhs 15 days after storage and further storage for 30 and 45 days adversely affected the number of viable progeny (1.85 & 0.98 lakh IJs at 30 & 45 days storage respectively).

(c) Formulation for transport

The shelf-life of sponge-based formulation of nematode varied depending on density of the sponge used in the study. The maximum survival (82%) was observed with of *S. carpocapsae* PDBC-

Table 18. Progeny production of *Heterorhabditis indica* PDBC-EN 13.31, *H. indica* PDBC-EN 13.4 and *Steinernema carpocapsae* in formulated cadavers

Isolate	Material	No of IJs produced days after storage (IJs in lakhs/cadaver)			
		15	30	45	60
H.indica PDBCEN 13.31	T+CC (1:1)	2.81	1.72	0.93	0.46
	T+CC (1:3)	2.79	1.84	1,03	0.51
	RCC	3.80	3.20	2,85	2.43
	T+CC+RCC	3.10	1.45	1,20	1.085
	Non-formulated cadaver	3.86	2.60	0.95	-
H.indica PDBCEN 13.4	T+CC (1:1)	2,28	0.78	0.58	0.35
	T+CC (1:3)	2,32	0.85	0.87	0.47
	RCC	3,50	3.12	2.12	1.98
	T+CC+RCC	2,85	1.23	1.89	0.95
	Non-formulated cadaver	3.80	2.45	0.78	-
S. carpocapsae PDBCEN 11	T+CC (1:1)	2.05	0.74	0.18	- -
	T+CC (1:3)	2.19	0.76	0.24	-
	RCC	2.75	1.85	0.98	-
	T+CC+RCC	1.95	1.095	0.43	-
	Non-formulated cadaver	2.75	0.2	-	-

Table 19. Survival of EPNs in sponge of different densities

Nematode sp.	Survival (%) after 5 months in storage density					
	4 months			6 months		
	High	Medium	Low	High	Medium	Low
S. carpocapsae	90	89	55	82	73	32
S. abbasi	84	80	55	60	55	32
H. indica PDBC-EN 13.31	52	50	8	15	9	0
H. indica PDBC-EN 13.4						
H. bacteriophora	35	30	5	0	0	0

NEN11 after 6 months of storage in high-density sponge followed by *S. abbasi* (63%).

Among the *Heterorhabditis* formulations, *H. indica* PDBC-EN13.31 and 13.4 showed the maximum shelf-life with survival of 74 - 76% in high density sponge three months after storage. Survival of *H. bacteriophora* was significantly low (35 & 30%) compared to *H. indica* isolates (Table 19). Low-density sponge could not retain nematode viability compared to higher density sponge types. The results indicate that the water holding capacity determine the concentration and shelf-life of nematodes in the sponge. Among three different concentrations tested, the lowest concentration of 150 lakh IJs per sponge of size 400 cm^2 was found optimum with maximum shelf-life of 200-210 (about 7 months) and 120-140 days for *S. carpocapsae* and *H. indica* respectively

Transport did not affect the viability and pathogenicity adversely. The viability of IJs in the formulation was 100% on receipt and after 15 days of storage also (i.e. 65 days after making the formulation) (Table 20). The survival of IJs was reduced to 90% under 35 days storage and further

Table 20. Survival and pathogenicity of nematodes extracted from formulation after transport from Bangalore			
Days after receipt of formulation	IJ viability (% survival)	Mortality (%) of fifth instar of *C. cephalonica* larvae after (h)	
		48	72
1 (51)	100	25	75
15 (65)	100	29	75
35 (85)	90	28	75
45 (95)	70	27	60
75 (125)	45	16	20

Table 21. *In vivo* production of EPN isolates at controlled temperature and RH (65%)			
Nematode isolate	Temperature (°C)	Yield (IJs in lakhs/larva)	Days for complete harvest
S. carpocapsae PDBC-EN 11	24	1.86	7
	26	2.94	3
S.carpocapsae PDBC-EN 6.11	24	1.78	7
	26	2.50	3
H. indica-PDBC-EN 13.31	24	1.70	9
	26	4.45	4
H. indica-PDBC-EN 13.4	24	1.65	10
	26	4.20	4
H. bacteriophora	24	2.20	9
	26	4.30	3

storage up to 45 and 75 days reduced the viability to 70 & 45 %.

(d) Optimization of *in vivo* mass production of EPN

The effect of temperature and humidity on the yield of ijs was studied *in vivo* production. The progeny production of all nematode isolates studied was maximum at 26°C and 65% RH. Maximum production observed was 4.4lakhs IJs/larva for *H. indica* PDBC-EN 13.31 followed by *H. indica* PDCB-EN 13.4 and *H. bacteriophora* (4.0 and 3.95 lakh IJs/larva respectively). *Steinernema carpocapsae* isolates, PDBC-EN 11 and PDBC EN 6.11yielded 2.94 and 2.83 lakhs Ijs/larva at the above mentioned conditions which was reduced to 1.86 and 1.65 when temperature was reduced to 24°C. Yield of *H. indica* isolates was also reduced at 24°C and 65% (Table 21).

In the experiment where RH was increased to 72% the production of IJs reduced irrespective of nematode isolates at 24 and 26°C. The maximum production of *H. indica* PDBC EN 13.31 was only 2.98 lakhs IJs compared to 4.4 lakhs at 26°C/65%RH (Table 22). The same trend was observed with other isolates also. Total number of days required for completion of production cycle varied at different set of conditions. Low temperature and high RH prolonged the production cycle with adverse effect on nematode multiplication and yield.

(e) Packaging for EPN formulation

Vacuum or nitrogen gas packing was as good and on a par with normal air packing without any effect on the shelf-life and viability. In 100% vacuum packing, the maximum viability in terms of survival of IJs was only 45% against the 98% survival in the 75% vacuum and 75% nitrogen packing and normal air packing. Survival was significantly reduced when stored for 60 and 90 days under the same conditions (8% in 100% vacuum and 18% in 100% nitrogen packing). In the

Table 22. *In vivo* production of EPN isolates at controlled temperature and RH (72%)			
Nematode isolate	Temperature (°C)	Yield (lakhs) /larva	Days for complete harvest
S. carpocapsae PDBC-EN 11	24	1.50	11
	26	2.54	8
S.carpocapsae PDBC-EN 6.1	24	1.30	9
	26	2.15	5
H. indica PDBC-EN 13.31	24	1.70	14
	26	2.98	14
H. indica PDBC-EN 13.4	24	1.50	15
	26	2.92	12
H. bacteriophora	24	1.24	14
	26	2.95	13

Table 23. Bioefficacy of *Arthrobotrys oligospora* against root-knot and reniform nematodes under pot conditions

Treatment	Cowpea reniform nematode			Tomato root-knot nematode		
	Nematode multiplication rate	Egg masses/g root	Juveniles/g root	Nematode multiplication rate	Egg masses/g root	Juveniles/g root
A. oligospora	1.88	30	36	1.94	40	42
A. oligospora + FYM	1.24	28	26	1.66	32	28
Nematode inoculated check	2.25	58	62	2.08	60	78

case of the three *Heterorhabditis* isolates tested, normal packing and package in 75% nitrogen were found more suitable than vacuum packing.

(f) Bioefficacy of EPN against white grubs in arecanut

Talc-based formulations of *H. indica* (PDBCEN 13.31) and *S. carpocapsae* brought about 47 –55% reduction in the white grub (*Leucopholis lepidophora*) population on arecanut in a farmer's plantation in Chickmagalur.

(xix) Biological suppression of plant parasitic nematodes

(a) Biological control of *Fusarium* and reniform nematode wilt complex in cotton:

Reniform nematodes (*Rotylenchulus reniformis*) predisposed cotton plants to *Fusarium* wilt, resulting in 45% seedling mortality under pot conditions within 30 days of plant emergence. Incorporation of *P. lilacinus* followed by *T. harzianum* (with a gap of 7 days) @ 10^9 spores/pot (2kg soil) each before sowing, reduced the seedling mortality to 8%.

(b) Bioefficacy of *Arthrobotrys oligospora* against root-knot and reniform nematodes under pot conditions and pathogenicity to EPN:

Application of a talc-formulation of *Arthrobotrys oligospora* PDBC-AO1 in nematode-infested soil reduced the root infection by root-knot and reniform nematodes in tomato and cowpea, respectively, under pot conditions (Table 23). Moist filter paper assay in glass Petri plates indicated that *A. oligospora* was safe to EPN juveniles.

(c) Relationship between initial water content of the media and yield of *Paecilomyces lilacinus* and *Pochonia chlamydosporia* in solid-state production

A definite relationship between initial water content of media and water activity was observed for bran and rice grain. It was observed that moisture content was a critical factor in solid-state production of both *P. lilacinus* and *P. chlamydosporia*. Initial water content of the media was as important as water activity in different stages of mass production, which were observed to be interrelated.

(d) Shelf-life and spore viability of *P. lilacinus* and *P. chlamydosporia* talc formulations in different packaging material

Talc formulations of *P. lilacinus* and *P. chlamydosporia* with 6-8% moisture stored in sealed aluminium sachets exhibited 92-96% spore viability after 12 months of storage at 8-10 °C and 88-92% viability at ambient conditions.

(e) Effect of drying on spore viability of *P. lilacinus* and *P. chlamydosporia*

Air-drying of talc formulations of *P. lilacinus* and *P. chlamydosporia* at a relative humidity of 40-60% for different durations gave samples with water activity of 0.10 to 0.98. Spore viability of *P. lilacinus* in talc formulation exhibited a negative correlation with water activity between 0.60 and 1.00, while spore viability of *P. chlamydosporia* exhibited a negative correlation with water activity above 0.76, at storage duration of 60 days.

(f) Effect of soil moisture on the germination of spores of *P. lilacinus* and *P. chlamydosporia*

Spore germination of *P. lilacinus* as affected by moisture was studied in red laterite soil at different moisture regimes at an incubation temperature of 28, 30 and 32°C with a simulated moisture content in PDA. A minimum water activity of 0.36 was ideal for germination of spores in red laterite soil at 28, 30 and 32°C in case of *P. lilacinus*, while a minimum of 0.39 water activity was ideal for *P. chlamydosporia* spore germination. For mycelial growth, a minimum water activity of 0.70 and 0.82 was ideal for *P. lilacinus* and *P. chlamydosporia* respectively in red soil at 28, 30 and 32 °C.

(g) Efficacy of talc formulations of *P. lilacinus* and *P. chlamydosporia* on pigeonpea cyst nematode

Incorporation of *P. lilacinus* and *P. chlamydosporia* formulated in talc at 20 kg/acre in pigeonpea at sowing resulted in 48-59 % reduction in cyst populations of pigeonpea cyst nematodes compared to untreated check in microplot trials at TNAU, Coimbatore and AAU, Anand. There was an 18 to 21% increase in pigeonpea yield in treated plots compared to untreated check.

5.1.2 AICRP ON BIOLOGICAL CONTROL OF CROP PESTS AND WEEDS

(i) Bioactivity and molecular characterization of native *B. thuringiensis* isolates

IARI

Bacillus thuringiensis var. *kurstaki* isolates along with standards were evaluated at 27 °C and 50-75% RH for their efficacy against two lepidopterans and the isolates AUG-4, AUG-5, AUG-7 were found to be highly toxic to neonates of *Earias vitella* and *Leucinodes orbonalis*. These isolates were positive for the presence of cry1, cry2, cry3 and cry4 on the basis of their PCR amplification with specific molecular markers.

(ii) Testing of bioefficacy of oil- and talc-based formulations of biocontrol agents against foliar diseases

GBPUA&T

Addition of FYM powder in spray mixture with talc-based formulation of *Trichoderma harzianum* and *Pseudomonas fluorescens* reduced disease incidence over talc-based formulation applied as such (Table 24).

Table 24. Effect of foliar application of talc and oil-based formulations of *Trichoderma harzianum* PBAT-43 (TH-43) or *Pseudomonas fluorescens* PBAP-27 (PsF-27) on brown spot intensity and yield of organically cultivated scented rice (cv. Kalanamak 3131)

Treatment	Disease intensity (%)	Yield (kg/ha)
TH-43 talc-based*	47.4	2470
TH-43 oil-based	32.4	2780
PsF-27 talc-based	33.5	2730
PsF-27 oil-based	27.0	3140
TH-43 + talc-based + FYM powder**	41.1	2680
PsF-27 talc-based + FYM powder	29.6	3070
FYM	74.0	1700
Control	76.3	1680
CD (p d" 0.05)	7.6	430

*@ 10g/l; **FYM @20g/l

PAU

Talc- and oil-based formulations of *T. harzianum* and *P. fluorescens* were evaluated against sheath blight of rice (cv. PR116) at Jandiala (Amritsar district) during 2006, and it was observed that incidence of disease before spray varied from 10.1 to 13.9 % in different treatments. After three sprays the incidence varied from 33.4 to 40.2 % but all the treatments were at on par with each other. So none of the treatment was effective. Similarly yield q/ha was also insignificant.

AAU(J)

The bioefficacy of oil- and talc-based formulations of *Trichoderma harzianum* and *Pseudomonas fluorescens* in different combination showed that the lowest (3.3%) occurrence of brown spot was observed in the plot treated with *Pseudomonas fluorescens* oil-based formulation and also in the treatment *P. fluorescens* (10 g/l) talc-based + FYM (20 g/l), but the maximum yield (3114.5 kg/ha) was recorded in the plot treated with *P. fluorescens* (10 g/l) talc-based + FYM (20 g/l) (Table 25).

(iii) Relative efficacy of mycoparasitic and systemic resistance inducing strains of *Trichoderma* against soil-borne and foliar diseases when applied through seed and soil

GBPUA&T

(a) Greenhouse studies

In the greenhouse study, when applied as seed treatment, all the antagonists reduced disease incidence caused by both sclerotia-forming (*R. solani, S. rolfsii* and *S. sclerotinia*) and non-sclerotia forming (*F. oxysporum pisi*) pathogens (Table 26). However, sclerotia-colonizing isolates (PBAT-16 and 12 and PBAT-43 against *R. solani*) were more effective against sclerotia forming pathogens whereas effective hyphal colonizers were more effective against *F. oxysporum pisi*, which does not form any sclerotia.

(b) Vegetable pea

In one of the trials seed treatment alone or along with foliar application of different biocontrol agents significantly reduced rust severity and

Table 25. Testing of bioefficacy of oil-based and talc-based formulation against foliar disease

Treatment	Brown spot (%)	Yield (kg/ha)
Foliar spray with *Trichoderma harzianum* (10 g/l)	3.7^{b}	3097.9^{a}
T. harzianum equivalent dose oil-based formulation	3.7^{b}	3058.0^{a}
Pseudomonas fluorescens (10 g/l) talc-based	3.4^{b}	3060.8^{a}
P. fluorescens equivalent dose oil-based formulation	3.3^{b}	3060.6^{a}
T. harzianum (10 g/l) talc-based + 20 g/l FYM	3.4^{b}	3079.0^{a}
P. fluorescens (10 g/l) talc-based + 20 g/l FYM	3.3^{b}	3114.5^{a}
Foliar spray with 20 g/l FYM powder	5.5^{a}	2869.0^{a}
Control	6.3^{a}	2752.3^{b}

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 26. Efficacy of different *Trichoderma* isolates against pathogens of pea under greenhouse conditions				
Isolate	Incidence (%)			
	S. sclerotiorum	*S. rolfsii*	*R. solani*	*F. oxysporum pisi*
PBAT-12	26^{a}	32^{ab}	32^{a}	30^{b}
PBAT-14	38^{b}	38^{bc}	34^{a}	22^{b}
PBAT-16	30^{a}	28^{a}	30^{a}	30^{b}
PBAT-43	30^{a}	38^{b}	32^{a}	10^{a}
Check	56^{c}	44^{c}	46^{b}	38^{c}

Means followed by the same letter in a column are not significantly different (P=0.05)

increased grain yield as compared to control. Defense-inducing isolate *T. harzianum* PBAT-39 was more effective than *T.harzianum* PBAT-43 and/or *P. fluorescens*.

(c) Organic vegetable pea

The efficacy of five antagonistic and/or ISR isolates of *Trichoderma* was evaluated in organically cultivated vegetable pea both in oil-based and talc-based formulations. These isolates were applied either as seed treatment alone or along with foliar application. All the isolates of *Trichoderma* spp., except PBAT-43, significantly increased green pod yield over control. Different isolates also increased seedling growth but differences from control were not significant. There was no incidence of any foliar disease even in control.

(iv) Large-scale field-demonstration of *Trichoderma* at farmers' field

GBPUA&T

Seed treatment with ISR strain of *T. harzianum* PBAT-39 followed by one spray with a mixed formulation of *T. harzianum* PBAT-43 (TH-43) and *Pseudomonas fluorescens* PBAP-27 (PsF) was demonstrated at 10 farmers' fields under organic cultivation covering 20 ha. One spray of *Beauveria bassiana* was given to both treated and control plots. Seed treatment with *Trichoderma* resulted in significantly higher germination. Foliar spray of mixed formulation of TH-43 + PsF-27 was given as soon as rust incidence was detected in traces. Although overall rust incidence was low in all the fields, it was invariably lower in *Trichoderma* treated plots. Significantly higher green pod yield was recorded in bioagent treated plots in all the fields (Table 27).

Table 27. Large-scale demonstration of effect of biocontrol agents on vegetable pea at farmers' fields under organic cultivation

Treatment	Seedlings/ m^2	Rust severity (%)	Yield (kg green pod/acre)
Farmers' practices	22.6	6.1	20.1
Biocontrol	29.6	3.5	25.9

Common Minimum Programme-based IPM module demonstrations were conducted in Golapar-Chorgalia area of Haldwani district of Uttarakhand on tomato covering 28.5 acres and 81 farmers. Major aim of the study was to reduce the application of chemical pesticides without affecting yield by promoting the biocontrolagents as a part of IPM module developed for tomato.

Common Minimum Programme	Colonization of FYM with *T. harzianum* PBAT-43 (TH-43) + *P. fluorescens* PBAP-27(PsF) + rock phosphate + use of vermicompost enriched with PsF-27 + rock phosphate + solarization of nursery soil + root dipping in suspension of TH-43+PsF-27
IPM Module	Use of about 50 g colonized vermicompost/FYM with each plant at the time of planting.Two sprays of TH-43 + PsF-27 (@10 g/ha) at 10 days interval starting 1 month after transplanting followed by one spray of 0.2 % Ridomil MZ 10 days later.Use of pheromone traps (@ 8 per acre).Three releases of *Trichocards* (@ 50000 /ha) at weekly interval. Spray of HaNPV (1.5 x 10^{12} POB/ha) One to two sprays of endosulfan (35 EC; 750 ml/ha) (need-based).

Use of TH-43 + PsF-27 treated seedlings and colonized FYM / vermicompost significantly reduced different diseases. Use of *P. fluorescens*

Table 28. Efficacy different yeast isolates on post harvest diseases of mango						
Treatment	Fruit surface (%) rotten after (days)					
	6		10		12	
	Totapuri	Dasheri	Totapuri	Dasheri	Totapuri	Dasheri
Isolate 1	0.9ᵃ	5.5ᵃ	17.7ᵇ	25.5ᵇ	36.4ᵇ	56.4ᵃ
Isolate 2	1.8ᵃ	4.1ᵃ	19.1ᵇ	24.1ᵇ	48.2ᶜ	56.8ᵃ
Isolate 3	1.4ᵃ	3.2ᵃ	19.5ᵇ	18.6ᵃ	27.7ᵃ	50.0ᵃ
Isolate 4	1.8ᵃ	5.9ᵃ	13.2ᵃ	31.8ᶜ	30.0ᵃ	63.6ᵇ
Isolate 5	2.7ᵃ	4.1ᵃ	31.8ᶜ	45.0ᵈ	67.3ᵈ	56.8ᵃ
Control	1.4ᵃ	5.5ᵃ	21.8ᵇ	30.9ᶜ	62.7ᵈ	93.6ᶜ

Means followed by the same letter in a column are not significantly different (P=0.05)

PBAP-27 colonized vermicompost reduced bacterial wilt, a problem difficult to handle by any chemical pesticide. Yield in IPM plots was as good as or better than non-IPM plots with extensive use of chemical pesticides. Biocontrol agents included in IPM modules reduced the number of chemical sprays from 10-17 to 2-4 out of which only one spray was of fungicide. The benefit: cost ratio was higher for IPM plots.

(v) Shelf-life of *Trichoderma* and *Pseudomonas* formulations

GBPUA&T

The population of *T. harzianum* as well as *P. fluorescens* (the formulations developed in mineral oil (D-C Tron Plus oil)) was above 10^8 cfu per ml even after 10 months of storage.

(vi) Biological control of pigeonpea cyst nematodes and disease complex

TNAU

Studies were conducted to control pigeonpea cyst nematode and wilt disease in pigeonpea with biocontrol agents. Combined application of *T. harzianum* 5 kg/ha plus *Pochonia chlamydosporia* 20 kg / ha, reduced eggs / cyst (24.7) and seedling mortality (10.6%), and increased seed germination (90.0%) plant height (29.5cm) and yield (610g/ plant).

(vii) Biological control of post-harvest fruit rot in mango

PDBC

Five microbes (yeast) cultures were tested for their efficacy in reducing post harvest spoilage of mango. In totapuri, the spoilage started from 6th day in control and in a few treated fruits. By 12th day more than 60% fruit surface was rotten in control while in fruits treated with isolate 3, it was only 27%. In the fruits treated with isolate 5 also, the rotting was very high (67%) (Table 28). In Dasheri, the rotting started from the second day after incubation and the rotting reached 93% in control by 12th day. In microbial isolate-treated fruits (isolates 1, 2, 4 and 5) the rotting of fruit surface was restricted to 56-63% while in the isolate 3 treated fruits it was 50%. The rotting was very fast during the last two days, i.e. 10th to 12th day of incubation.

(viii) Standardization of method for genetic transformation of *T. harzianum* using gene gun

GBPUA&T

Gene gun (biological ballistic) procedure was standardized for transforming *T. harzianum* strain PBAT-43. Fungal conidia were bombarded using helium-driven gene gun device to accelerate tungsten particles coated with plasmid containing a bacterial hygromycin B-resistance gene (hygB) as a dominant selectable marker. Hygromycin B-resistant transformants were recovered from *T. harzianum* strain PBAT-43. Southern analysis of hygromycin-resistant progenies showed that the transforming sequences were integrated into the genome of the recipient strain.

5.2 BIOLOGICAL SUPPRESSION OF SUGARCANE PESTS

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

CCSHAU

The incidence of scale rose from 14.8% (at the time of ratooning) to a maximum of 58.3% in untreated check after one month of stripping of lower leaves and just before the release of first consignment of the predator, *Chilocorus nigrita*. In IPM module and the farmers practice plots the incidence at this interval was 49.3 and 59.4%, respectively. After the second liberation of the predators also, the IPM plot recorded lower incidence and intensity of the scale than the plots under check and the farmers practice. At harvest, however, the incidence and intensity of scale was just marginally lower in IPM plots and statistically not significant. The infestation of scale in farmers practice plot was also not much different from untreated check at the time of harvest.

(ii) Maintenance and supply of *Epiricania melanoleuca* for the biological control of *Pyrilla perpusilla*

IISR

The spatial variations in the population size of various stages of pyrilla and their parasitoids was observed in the months of August and September 2006 at the IISR Research Farm, Lucknow. Population counts were made at interval of 15 days on 10 plant (each plant, 3 leaves i.e. upper, middle and lower selected) in each block with variety CoS 95255 and CoSe 92423.

The immature stages (eggs and nymphs) and adult of pyrilla was low in both variety during August. However, cocoons of *Epiricania* was more (1-2/leaf) on middle & lower leaves in variety CoSe 92423. There was no trend of *Epiricania* cocoons on upper, middle and lower leaves in variety CoS95255.During September, host population was very low, it seems that egg, nymphal and adult parasitoids had checked the population.

At Pravaranagar (IISR Biocontrol Centre), maximum pyrilla population was observed in second fortnight of August 2006 i.e. 35 to 42 adults and 55 to 74 nymphs/100 clumps. Fresh eggs and cocoons of *Epiricania* were also observed in June to Nov to check the host population. Eggs and cocoons of *Epiricania* were collected from areas of predominance and distributed to farmers of village around Padmshri Dr.Vithalrao Vikhe Patil S.S.K.Ltd., Pravaranagar, Ahmednagar.

PAU

The incidence of sugarcane pyrilla was low, throughout the season in the entire state. So, there was no need to redistribute the *E. melanoleuca* in infested area.

CCSHAU

During 2006 sporadic incidence of *Pyrilla perpusilla* was observed in Haryana from August to October. The nymphal-adult parasitoid, *Epiricania melanoleuca* and egg parasitoids of leaf hopper *P. perpusilla* were multiplied at Biopesticide Laboratory, RRS, Karnal and Central Biological Control Laboratories located in the premises of Cooperative Sugar Factories, Sonipat, Maham, Shahbad and Jind. A total of 23,572 egg-masses and 32,774 cocoons of *E. melanoleuca* and 13,778 egg masses of egg parasitoid of *P. perpusilla* were produced/ collected and supplied to farmers for their liberation in 7,637, 5,338 and 7,832 acres of sugarcane, sorghum and rice fields. Simultaneously, the laboratories also produced 30,82,54,000 egg parasitoids, *T. chilonis* and 2,08,04,000 *T. japonicum* and supplied these to farmers of Haryana state for inundative releases in 15,445 and 13,425 acres of borer-infested fields of sugarcane and rice, while, the white muscardine *B. bassiana* and *B. brongniartii* was produced for experimental purpose.

(iii) Field evaluation of *T. chilonis* against plassey borer

AAU(J)

The field evaluation of *T. chilonis* against *Chilo tumidicostalis* was conducted at Sugarcane Research Station, Buralikson.

The farmers practice plot was taken at farmers' field located in a village near to SRS, Buralikson. The sugarcane variety Dhansiri (CoBLN 9605) was grown in the two locations. In the released plot, *T. chilonis* @ 50,000/ha was released at 10 days intervals and altogether 9 releases were made. The first release was made after 50 DAP of crop against *C. tumidicostalis*. Observations were made on per cent incidence of the pest in the last fortnight of May onwards for the both cropping season. The natural egg parasitism was determined by placing *C. cephalonica* egg cards containing 50 eggs/card at 5 different spots of the location.

The results showed that *T. chilonis* had good impact in reducing the incidence of *C. tumidicostalis* in the released plot, which was 23.0% only as against 49.5% in the farmers' field. Biocontrol plot recorded an yield of 79.2 t/ha as against 58.0 t/ha in farmer's plot.

(iv) Demonstration on the use of *T. chilonis* (temperature-tolerant strain) against early shoot borer at two locations

PAU

Field evaluation of temperature-tolerant strain of *T. chilonis* developed by PDBC was carried out at village Gohawar (Distt. Jalandhar) and village Paddi Khalsa (Distt. Kapurthala). It was compared with chemical control and untreated control. *T. chilonis* was released 8 times, during mid - April to end – June, at 10 days interval @ 50,000 per ha. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg/ha, after 45 days of planting. The plot was size 20 ha for temperature tolerant strain and 0.4 ha each for chemical control and untreated control at each location. Each plot was sub-divided into 5 parts to record the observations. Egg masses of early shoot borer were collected from each plot to record parasitisation.

The data revealed that the incidence of early shoot borer at both the villages, viz. Gohawar and Paddi Khalsa in control (17.5%) was significantly higher than that in temperature tolerant strain of *T. chilonis* (8.2%) and chemical control (7.7%). The mean incidence in temperature tolerant strain of *T. chilonis* was on a par with chemical control. The parasitisation in released field (24.7%) was significantly higher than in chemical control (2.8%) and control (3.0%). The mean yield of both the locations was highest in chemical control (748.5 q/ha) followed by temperature-tolerant strain of *T.chilonis* (727.5 q/ha) and control (686.0 q/ha).

It can be concluded that 8 releases of temperature-tolerant strain of *T. chilonis* developed by PDBC, Bangalore @50,000/ ha was on a par with chemical control for the management of early shoot borer, and reduced the incidence by 53.2 %. The cost benefit ratio in release field (1:9.1) was higher than in chemical control (1: 6.2).

The pooled data of two years (2005 &2006) at 10 days interval during end April to mid June @ 50,000 per ha reduced the incidence of the borer by 52%. The egg parasitism in release fields was 26.7% as compared to 1.5% in control (Table 29).

Table 29. Large-scale demonstration of the effectiveness of *Trichogramma chilonis* (temperature-tolerant strain) against *Chilo infuscatellus* in Punjab during 2005 & 2006

Parameter	Year	*T. chilonis*	Chemical control (@ 25 kg/ha)	Control
Mean incidence (%) of *C. infuscatellus*	2005	6.8	6.6	13.8
	2006	8.2	7.7	17.5
	Mean	7.5	7.2	15.6
Reduction in damage over control (%)	2005	50.7	52.2	-
	2006	53.2	55.9	-
	Mean	51.9	54.1	-
Parasitism (%)	2005	28.7	0.0	0.0
	2006	24.7	2.8	3.0
	Mean	26.7	1.4	1.5

(v) Demonstration of efficacy of *T. chilonis* for the management of *Chilo auricilius*

PAU

The efficacy of *T. chilonis* was demonstrated over an area of 20 ha each at village Paddi khalsa (Distt. Jalandhar) and village Karni Khera (Distt. Ferozepur) for the management of stalk borer, *C. auricilius*. The parasitoids were released 12 times at 10 days interval during July to October @ 50,000 per ha. The control plot was 0.2 ha at two locations. The incidence of stalk borer and per cent parasitism was recorded from both the plots.

The incidence of stalk borer in control was 16.9 % as compared to 5.9 % in release field at Karni Khera, which resulted in 64.7 % reduction in damage. The % parasitisation in release fields was high (76.1%) as compared to 5.0 % in control at Karni Khera. At Paddi khera, the incidence of stalk borer in release field was 5.4 % and parasitism 46.0 as compared to 16.3 % incidence and 4.9 % parasitism in control thus, resulting in a reduction of incidence by 66.8%. It can be concluded that 12 releases of *T. chilonis* @ 50,000 per ha at 10 days interval proved effective and reduced the incidence of stalk borer by 65.7%.

The pooled data of two years (2005 & 2006) also revealed that releases of *T. chilonis* reduced the incidence of stalk borer by 63.3%. The parasitism in release fields was 43.9% as compared to 4.4 % in control.

(vi) Large-scale demonstration of biocontrol-based IPM against stalk borer, *Chilo auricilius*

PAU

Large-scale demonstration of effectiveness of *T. chilonis* against stalk borer over an area of 3,500 acres was carried out in collaboration with two sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar and Morinda Co-operative Sugar Mills Ltd. Morinda. The egg parasitoid, *T. chilonis* was released from July to October in both the mill areas at 10 days interval @ 50,000/ha. The incidence of *C. auricilius* at Nawanshahar and Morinda in IPM fields was 3.9 and 1.6 % respectively. The corresponding figures in control fields were 5.8 and 3.2 %. The mean reduction in damage over control in both the mills was 42.3 %.

In large-scale demonstration, 12 releases of T. *chilonis* @ 50,000 per ha at 10 days internal during July to October reduced the incidence of stalk borer by 42.3 %. The pooled data of two years (2005 & 2006) revealed that releases of *T. chilonis* reduced the incidence of stalk borer by 48.9 % (Table 30).

Table 30. Large-scale demonstration of biocontrol-based IPM on sugarcane in two sugarcane mills in Punjab during 2005 and 2006

Treatment			Doaba Co-op. Mills Ltd.,	Morinda Co-op. Sugar Mills, Nawanshahar	Total/ Mean Morinda
Area covered during 2005 & 2006 (acres)			3000	4000	7000
Incidence of *C. auricilius* (%)	IPM*	2005	4.6	2.0	3.3
		2006	3.9	1.6	2.7
		Mean	4.3	1.8	3.0
	Control	2005	6.7	9.8	8.3
		2006	5.8	3.2	4.5
		Mean	6.3	6.5	6.4
	Reduction (%) over control	2005	31.3	79.6	55.5
		2006	32.4	52.2	42.3
		Mean	31.9	65.9	48.9

(vii) Field evaluation of *T. japonicum* against *Scirpophaga excerptalis*

PAU

Field evaluation of *T. japonicum* against the top borer, *S. excerptalis* was carried out at village Gohawar (Distt. Jalandhar). It was compared with chemical control and untreated control. The plot size was 0.2 ha for each treatments. The parasitoid, *T. japonicum* was released 8 times at 10 days interval during April to June @ 50,000 per ha. In chemical control, phorate (Thimet 10G) @ 30kg/ha was applied during the first week of July. Each plot was divided into five parts to record the observations. The egg masses of *S. excerptalis* were collected to record parasitisation.

The incidence of top borer in control plot (15.7%) was significantly higher than in *T. japonicum* release (7.7%) and chemical control (7.6%) plots (Table 31). The mean parasitism of eggs of *S. excerptalis* in *T. japonicum* release plot, chemical control and control plot was 25.5, 1.3 and 1.4% respectively. The yield in control was significantly lower than in release fields and chemical control the later two being on a par with each other. The cost: benefit ratio was 1:13.2 in release field as compared to 1: 5.9 in control. It can be concluded that 8 releases of *T. japonicum* at 10 days interval during April to June @ 50,000 per ha are as effective as chemical control for the control of top borer

The pooled data of three years (2004 to 2006) revealed that 8 releases at 10 days interval of *T. japonicum* during April to June @ 50,000 per ha reduced the incidence of top borer by 50.8 %. The cost: benefit ratio of release field (1:18.6) was higher than that of chemical control (1: 9.6) (Table 32).

(viii) Biological suppression of white grubs using FYM enriched with *Beauveria bassiana*

CCSHAU

The lowest number of grubs was recorded in plots provided with FYM containing the highest dose of *B. bassiana* i.e. $6x10^{10}$ conidia/kg. The infectivity ranged from 18.3 to 29.4% being maximum in the grubs collected from plots treated with the highest concentration of the fungus.

(ix) Biological control of the sugarcane woolly aphid

(a) Population dynamics of the woolly aphid, *Ceratovacuna lanigera* and its natural enemies

TNAU

The study was conducted at Vellalore,

Table 31. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Gohwar (Distt. Jalandhar) Punjab during 2006

Treatment	Incidence of *S. excerptalis* (%)	Reduction over control (%)	Parasitism (%)	Yield (kg/ha)	Cost: benefit ratio
T. Japonicum	7.7^a	51.2	25.5^a	77180^a	1:13.2
Phorate 10G @ 30kg/ha	7.6^a	51.6	1.3^b	77280^a	1:5.9
Control	15.7^b	-	1.4^b	71160^b	-

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 32. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Gohwar (Distt. Jalandhar) during 2004-06

Treatment	Incidence of *S. excerptalis* (%) (2004-06)	Reduction over control (%)	Parasitism (%)	Yield (q/ha)	Cost: benefit ratio
T. japonicum	8.5^a	50.8	23.4^a	733.0	1:18.6
Phorate 10G @ 30kg/ha	8.2^a	52.2	1.6^b	736.6	1:9.6
Control	17.2^b	-	1.9^b	655.4	-

Means followed by the same letter in a column are not significantly different (P=0.05)

Coimbatore district on sugarcane cultivar, Co 86032 during March 2006-February 2007. The observations commenced on three months old crop. During August 2006, the lowest number of aphid population was recorded (4.9 aphids / 6.5 cm^2). The population increased from September onwards. It started decreasing in February 2007. The predator *Dipha aphidivora* appeared in higher numbers during October and November 2006 wherein more woolly aphid population was noticed. The natural occurrence of the predatory brown lacewing *Micromus igorotus* was at a lower density than *D. aphidivora*. During the last two years, *D. aphidivora* was the predominant predator of woolly aphid. Maximum temperature showed negative correlation with the woolly aphid population, while minimum temperature and relative humidity showed positive correlation. The rainfall and wind speed showed significant negative correlation with the woolly aphid population. Weather parameters had no significant effect on *D. aphidivora* or *M. igorotus* populations.

AAU(J)

The population dynamics of woolly aphid and its natural enemies were carried out at Sugarcane Research Station, Buralikson from June 2006-February 2007 for both the cropping seasons of 2005 and 2006. Observations of woolly aphid and its natural enemies were recorded at weekly intervals. The pest along with its natural enemies was noticed from first week of June during both the seasons. Based on survey data of two years, the maximum mean no. of woolly aphid in 6.5 sq. cm

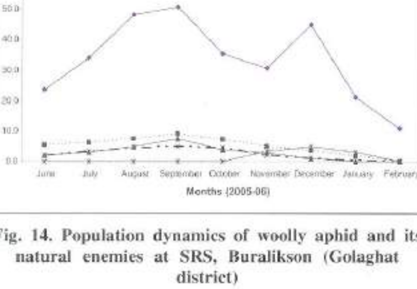

Fig. 14. Population dynamics of woolly aphid and its natural enemies at SRS, Buralikson (Golaghat district)

leaf was 50.8 in September followed by August (48.3) and December (45.0) (Fig. 14). Similarly, *D. aphidivora*, *Micromus* spp. and *Syrphid* spp. were found to be maximum (9.0, 7.5 and 4.9/leaf) during September. The population of *Encarsia* was noticed from November onwards with a mean of 3.3/leaf. The maximum (5.0/leaf) was observed during December. The predators recorded per leaf over the period of observations were in the order of *D. aphidivora* > *Micromus* > *Syrphid*.

The influence of various meteorological parameters, viz. temperature (maximum and minimum), relative humidity (morning and evening), total rainfall, no. of rainy days and wind velocity were correlated with the population fluctuation of woolly aphid and its different natural enemies. The correlation analysis showed that the population build up of woolly aphid had a positive but non significant correlation with temperature (maximum and minimum), no. of rainy days and wind velocity. Total rainfall and relative humidity (morning and evening) showed negative impact on population build up of woolly aphid. But the population build up of *D. aphidivora*, *Micromus* and *Syrphid* showed significant positive correlation with the maximum and minimum temperature. Relative humidity (morning) had a positive significant correlation with the population build-up of *Encarsia*.

ANGRAU

Incidence of the pest and presence of natural enemies was recorded in four of the seven agro-climatic zones of Andhra Pradesh, viz. Southern Telangana Zone (STZ), Northern Telangana Zone (NTZ), Krishna Godavari Zone (KGZ) and Southern Zone (SZ). The incidence of the woolly aphid was negligible during 2006-07.

MPKV

The data on sugarcane growing area and cropped area infested by woolly aphid were collected district- and division-wise in Maharashtra. The overall infested area of sugarcane by woolly aphid was 6.9% in the state. The pest incidence noticed was maximum in Aurangabad division (28.1%) and minimum in Nasik division.

To assess the impact of natural enemies, the sugarcane fields in major crop growing area from four agro-climatic zones of Maharashtra were surveyed during August 2006-February 2007. The observations on percent infestation, intensity rating and natural enemies were recorded on 20 clumps/ field and as such 3 fields from each of 5 villages in each zone were surveyed. The pest infestation was low in Ghat, Sub Montane and Plain zones of Western Maharashtra wherein activity of the predators, *M. igorotus* and *D. aphidivora* was predominant. *Micromus igorotus* was active from August to December 2006 in the Ghat, Sub Montane and Plain zones with its peak (6.0 larvae/ leaf) in Sub Montane zone. The occurrence of *D. aphidivora* was higher in sub Montane and Plain zones of the state from November 2006 onwards, while syrphids were recorded at low level. However, the woolly aphid infestation was higher in scarcity zone where the population of the predators was low.

In Pune, the pest infestation started in the 2nd week of July 2006, but it drastically reduced in September 2006 due to heavy rains in August-September 2006. Thereafter, the pest reappeared and reached its peak in December 2006. The predator, *M. igorotus* remained active from August to December 2006, whereas *D. aphidivora* was not observed till October 2006.

CCSHAU

Surveys of Cooperative and Private sugar mill zones were conducted during post monsoon period as also information was sought from the cane development staff of the mills and State Department of Agriculture on the occurrence of the pest. White woolly aphid was not recorded any where in Haryana during the last three seasons.

SBI

Aphid activity decreased from April 2006 up to May-June. It showed an upward trend from July onwards reaching a peak in November-December. *Dipha* numbers also showed a similar trend. *Micromus* numbers have generally been lower than *Dipha* numbers. There was a sudden reduction in aphid populations towards December end and early January 2007.

VSI

The seasonal incidence of the woolly aphid and its predators was studied at VSI, Pune. The pest was not noticed up to three months of crop age however, from first fortnight of December 2005 woolly aphid incidence was initiated. The average woolly aphid population / 6.25 cm^2 reached to 25.47. Incidence started to decline from February, 2006 with average 17.68 woolly aphid population/6.25 cm^2. No woolly aphid incidence was noticed during April to June months. Incidence reappeared during July and increased afterwards, however, maximum population was observed during December (88.64 woolly aphids/ 6.25 cm^2).

The peak population of the pest was noticed during November-December. During June to October the average woolly aphid population per 6.5 cm^2 was below 50 and the total rainfall and number of rainy days during this period was 1076 mm and 103 days. The heavy rains during this period seems to be the key factor for limiting the woolly aphid population. During the year 2006 the woolly aphid intensity rating was maximum during December. But the intensity rating was below 2.5 throughout the year and average intensity rating of woolly aphid for the year was just 0.91.

The woolly aphid incidence showed positive correlation with morning (0.45) and afternoon (0.20) RH, number of rainy days (0.09) and number of cloudy days (0.27 and 0.14) however, negative correlations are noticed with minimum (-0.32) and maximum (-0.20) temperature and sunshine hours (-0.24). Among all the three predators, *D. aphidivora* showed highly significant positive correlations (0.71) with woolly aphid incidence. However, all the three predators showed the positive correlation with woolly aphid incidence.

During September, 2006, highest average of 0.76 larvae and pupae/leaf of *D. aphidivora* population and lowest woolly aphid population of 16.67/ 6.25 cm^2 was recorded in South Maharashtra followed by Central Maharshtra (0.67 larvae and pupae of predator/leaf and 52.35 woolly aphid population of 16.67/6.25 cm^2). Very low predator development of 0.05 larvae and pupae/leaf and highest woolly aphid population of 77.12/ 6.25 cm^2 was noticed in North East Maharashtra. Due to the excellent development of *D. aphidivora* during the month of September (0.76) and October (0.57), the average population of woolly aphid declined to nil in the Southern Maharashtra. The woolly aphid

(12.45) reappeared in December, 2006 with immediate development of predators (0.05) and this helped in keeping the sugarcane free from woolly aphid incidence in the month of January. During 2006, the highest *D. aphidivora* population of 2.42 larvae and pupae/leaf was recorded in the Central Maharashtra in October, due to which the woolly aphid population in Central Maharashtra was reduced from 52.35 to 13.65/6.25 cm^2. In northeast Maharashtra initial woolly aphid incidence was severe with very low predator development of 0.05 larvae and pupae of predator /leaf. With increase in predator population from October (0.95) to November (0.89), the population was reduced to 22.65/ 6.25 cm^2 in the month of November.

(b) Mass production of predators of woolly aphid

TNAU

Shade net multiplication of *D. aphidivora* was carried out in Eastern block of TNAU, Coimbatore from July 2006 to January 2007. Shade nets of dimension 5 x 5 x 4 m in four locations were erected when the aphid infestation reached 60 %. All pre existing predator larvae and adults were removed and the shade nets erected and closed in August. When 90% of the leaves were fully infested by woolly aphid, first release of *Dipha* larvae @ 10/leaf was done. The pest and *Dipha* multiplied very fast within the shade net.

MPKV

To standardize the method for mass multiplication of *D. aphidivora* in shade nets on woolly aphid, the sugarcane crop (cv. Co 94012) was planted on the research farm of Entomology Section, College of Agriculture, Pune in the months of February, April and May, 2006 in 5 x 5 m blocks. The shadenet (50%) with bamboo structures of 5 x 5 x 4 m size were erected on sugarcane crop of 6, 7 and 8 months old. In all, 21 shade nets were erected. The woolly aphid colonies in shade nets were established by artificial inoculation and then release of *D. aphidivora* @ 50 larvae/ pupae in each shade net was carried out.

Due to heavy rains during *Kharif* season, the woolly aphid population as well as *D. aphidivora* was not established on 6 months old sugarcane crop. However, the pest incidence was noticed on 7 and 8 months old crop in November and December 2006, wherein inoculative release of the predatory larvae was carried out at 30 to 40% woolly aphid infestation. This has resulted in better development of *D. aphidivora* larvae (2,540 larvae/ shade net) on seven months old sugarcane crop.

SBI

In continuation of the earlier studies on development of mass multiplication method for the predator, *D. aphidivora* was reared in GI trays in 10 batches. The predator output in the batches and the mean recovery rate were comparable to those obtained in earlier studies.

VSI

Sugarcane was planted in the shadenet and polyhouse. The artificial inoculation of woolly aphid was done twice in each shade net and poly house. After establishment of woolly aphid, predator culture was inoculated in poly house and shade net. The nucleus culture of predator was supplied to the sugar factory for further multiplication and distribution for the control.

Tissue-culture plantlets of sugarcane (cv. Co 86032) were planted in polyhouse and shadenet. In each polyhouse and shadenet, 150 plantlets were planted at 2.5 ft distance and row to row distance was 2.5 ft to achieve more number of leaves for maximum production of predators. A temperature of 26 ^{0}C and 78% RH were maintained during tillering and during grand growth period temperature of 20 ^{0}C was maintained. The germination and growth of sugarcane was satisfactory in polyhouse and shadenets.

About 1000 and 0.1 million mixed population of woolly aphid in each polyhouse and shade net were released respectively in two installments. In the polyhouse, due to the controlled conditions the woolly aphid establishment was early as compared to the shade net.

A maximum of 8.0 larvae and pupae were established at 75 days after the release of predators in poly house. In shade net, maximum population of *Dipha* (6.1 larvae+ pupae/ leaf) larvae and pupae was observed 90 days after release of predators.

Dipha multiplied in polyhouse and shade-net were further supplied to the 39 sugar factories. From 99 m^2 and 91.43 m^2 area of polyhouse and shade net, 66,500 and 2,20,000 larave/ pupae of *Dipha* (from 5 shade nets) were supplied within five months period.

(c) Effect of agronomic practices on the incidence of woolly aphid

TNAU

The study was carried out at Coimbatore campus of TNAU. The two practices followed were:

Recommended practice	Farmer's practice
Paired row of 3' between rows and 5' between pairs	Rows of 3' distance
Drip irrigation	Flood irrigation
Nitrogen fertilizer normal dose with 25% through organic source	1.5 times more N
Intercrop as per local acceptance	No intercrop
Detrashing and mulching between rows	Detrashing and removal of trash
Removal of leaves with initial infestation and destroy.	No removal of leaves with initial infestation and burning.

Higher clump infestation was observed more in farmer's practice (28.2%) than in recommended practices (16.3%). Pest intensity rating (1.6), natural enemies like *Dipha* (2.1) and *Micromus* (0.4) were more in farmers' practice than in recommended practice. In general the copious application of irrigation and fertilizers in farmers' practice plot seems to have favoured the growth and development of woolly aphid.

MPKV

The experiment was laid out on the research farm of Central Sugarcane Research Station, Padegaon. The planting of sugarcane (var. Co 86032) was done on 0.2 ha area on November 18, 2006. Each treatment plot is divided into twelve sectors as per the protocol. The observations were recorded on woolly aphid incidence on 20 clumps/ sector, pest number (6.5 cm^2 area/ leaf), intensity rating (1–6) and natural enemies population on 5 clumps at monthly intervals.

Treatment details:

T_1 : Recommended practice

A] Paired row of 75 cm between rows and 150 cm between pairs

B] Optimum water use

C] Nitrogen fertilizer normal dose (225 N:115 P:115 K) with 25 % through organic sources

D] Intercrop (cabbage) and border row of cowpea

E] De-trashing and mulching between rows

F] Removal of leaves with initial infestation and destruction by burning

T_2 : Farmer's practice

A] Rows of 75 cm distance

B] Frequent irrigation

C] Nitrogen dose 1.5 times more than normal dose per ha

D] No intercrop

E] De-trashing and removal of the trash from the plots

F] No removal of leaves with initial infestation

The woolly aphid incidence was not observed in both the treatment plots until March 2007.

VSI

Effect of N fertilizers on incidence of woolly aphid.

Treatments: Four

T_1 –Recommended dose of N:P:K fertilizers (250:115:115)

T_2 –Recommended dose of N:P:K fertilizers + 25 % extra dose of N fertilizers (312.5:115:115)

T_3 –Recommended dose of N:P:K fertilizers + 50 % extra dose of N fertilizers (375:115:115)

T_4 –Recommended dose of N:P:K fertilizers + 75 % extra dose of N fertilizers (437.5:115:115)

Replications: Five

Additional dose of N fertilizers increased the tillering, but made the sugarcane more succulent for the woolly aphid attack, which ultimately resulted in heavy incidence of woolly aphid. At six month after planting the sugarcane with recommended dose of N:P:K fertilizers + 75 % extra dose of N fertilizers recorded heavy incidence of 99.23 woolly aphid population / 6.25 cm^2 followed by treatment with recommended dose of N:P:K fertilizers + 50 % extra dose of N fertilizers (69.40/ 6.25 cm^2) and Treatment with recommended dose of N:P:K fertilizers + 25 % extra dose of N fertilizers(53.32/ 6.25 cm^2 where as sugarcane plot with only recommended dose of NPK fertilizers recorded the delayed woolly aphid infestation and further woolly aphid population built up was also slower. Additional dose of N fertilizers helped in early initiation of woolly aphid attack in sugarcane and further built-up of woolly aphid population.

(d) Field release and evaluation of predators

AAU (Navsari)

Under shadenet condition the mass production of *M. igorotus* was done during October-November 2006. Mass production of *M. igorotus* was started on natural host under the shade net house (10 sq.m area) condition. Average two larvae of the predator per leaf were observed after 40 to 50 days of inoculation. Shade net-reared *M. igorotus* were released in the infested field at Ena village of Bardoli sugar factory area. A total of 252 larvae of *M. igorotus* were released in two installments at weekly intervals (Table 33). First release was made in the first week of December. The initial population density of aphid was 132.54 aphids/leaf and it came down to 97.82 aphids/leaf a week after release. Second release was made 7 days after first release.

Table 33. Impact of release of *Micromus igorotus* on woolly aphid population at Ena village during December 2006 and January 2007

Date	Average number of aphids/leaf
05/12/2006	132.5
12/12/2006	97.8
19/12/2006	76.3
26/12/2006	50.9
02/01/2007	28.6
09/01/2007	6.2

TNAU

Experiments to fix the Dipha release rate were conducted at Vellalore and Puthur villages. *Dipha* pupae were released @1000, 2000 and 3000 per ha three times at 10 days interval. Observations were made at I, II, III and IV months after release. At Puthur trial 88.2% reduction of woolly aphid infestation was achieved four months after release. The dose of one thousand pupae per ha was on par with 2000 and 3000 larvae per ha in efficiency of woolly aphid suppression (Table 34). Similar results were obtained from the Vellalore trial also (86.1%) (Table 35). Based on these studies, a release rate of 1000 larvae per ha was adopted for further field release as increasing the release rate further did not increase the level of woolly aphid suppression.

At a release rate of 1000 pupae/ha, the following study was conducted at three locations, i.e. Puthur, Vellalore and Elayamuthur. In a three hectare field four spots of 0.25 ha size was selected with the following conditions.

i. Heavy infestation of woolly aphid with natural occurrence of *D. aphidivora.*

ii. Initial infestation of woolly aphid with natural occurrence of *D. aphidivora.*

Table 34. Evaluation of efficiency of *Dipha aphidivora* at different doses and at different number of releases (Puttur, Coimbatore district)

Dose (pupae/ha)	No. of releases	Reduction of woolly aphid infestation (%) DAR			
		30	60	90	120
1000	1	22.4[b]	38.6[b]	62.4[c]	75.8[d]
	2	25.9[a]	45.8[a]	68.9[b]	82.3[b]
	3	26.2[a]	46.2[a]	73.8[a]	88.2[a]
2000	1	21.9[b]	40.0[b]	62.8[c]	77.9[c]
	2	25.7[a]	46.1[a]	68.7[b]	81.9[b]
	3	25.9[a]	46.3[a]	74.0[a]	88.6[a]
3000	1	22.5[b]	41.0[b]	62.7[c]	77.8[c]
	2	26.1[a]	46.5[a]	70.1[b]	82.6[b]
	3	26.3[a]	46.7[a]	74.1[a]	88.2[a]

DAR: Days after release. data are means of 25 values, Means followed by similar letters are not significantly different (P=0.05) by DMRT

Table 35. Evaluation of efficiency of *Dipha aphidivora* at different doses and at different number of releases (Vellalore, Coimbatore district)

Dose (pupae/ha)	No. of releases	Reduction of woolly aphid infestation (%) DAR			
		30	60	90	120
1000	1	20.3^{b}	36.5^{b}	60.3^{c}	73.7^{d}
	2	23.8^{a}	43.7^{a}	66.8^{b}	80.2^{b}
	3	24.1^{a}	44.1^{a}	71.7^{a}	86.1^{a}
2000	1	19.8^{b}	38.0^{b}	60.7^{c}	75.8^{c}
	2	23.6^{a}	44.0^{a}	66.6^{b}	79.8^{b}
	3	23.8^{a}	44.2^{a}	72.0^{a}	86.5^{a}
3000	1	20.4^{b}	39.0^{b}	60.6^{c}	75.7^{c}
	2	24.0^{a}	44.4^{a}	68.0^{b}	80.5^{b}
	3	24.1^{a}	44.6^{a}	72.0^{a}	86.1^{a}

DAR: Days after release, data are means of 25 values. Means followed by similar letters are not significantly different (P=0.05) by DMRT

iii. Initial infestation of woolly aphid and no natural occurrence of *D. aphidivora*.

iv. Initial infestation of woolly aphid without the natural occurrence of *D. aphidivora* + inoculative release of *D. aphidivora*.

The predator was first released @ 1000/ha and the second release after 10 days. The predator exercised substantial control of the aphids by 120 days in all the three seasons (Table 36). By the fifth month, the population of the aphids was suppressed by 90-100% and by 180 days there was 100% control in all the three locations.

SBI

Dipha aphidivora obtained from laboratory cultures was released in an experimental plot of 0.4 ha at the rate of 1000 per ha at 10 spots in the field. A control plot was maintained in a different location. Post-release mean aphid rating in release plot showed a decrease of 10.8% compared to pre-release observation, though not significant. During the same period, *Dipha* population showed a significant increase. In a second trial, there was an increase in *Dipha* population following release, though not significant, but the decrease in aphid rating was significant (86%). In both trials, subsequent observations showed a rapid decline in aphid population. This short period witnessed the first ever occurrence of *Encarsia flavoscutellum* after its introduction at Coimbatore by PDBC.

Table 36. Evaluation of efficacy of *Dipha aphidivora* against woolly aphid

Treatment	Reduction of infestation (%) DAR					
	Vellalore		Puthur		Elayamuthur	
	120	150	120	150	120	150
Heavy infestation + natural enemies + *Dipha* release	93.6	100.0	82.5	90.0	84.9	92.5
Initial infestation + natural enemies + *Dipha* release	97.2	100.0	86.1	91.0	88.5	93.5
Initial infestation + no natural enemies + *Dipha* release	95.3	100.0	85.1	90.8	87.6	93.3
Initial infestation + without natural enemies + Inoculation of *Dipha* release	94.8	100.0	84.7	90.2	86.9	92.7

VSI

Treatments: Four

T_1 – Release of *D. aphidivora* @ 1000 larvae & cocoons /ha. in 3 month old sugarcane infested with woolly aphid

T_2 – Release of *D. aphidivora* @ 1000 larvae & cocoons /ha. in 4 month old sugarcane infested with woolly aphid

T_3 – Release of *D. aphidivora* @ 1000 larvae & cocoons /ha. in 5 month old sugarcane infested with woolly aphid

T_4 – Release of *D. aphidivora* @ 1000 larvae & cocoons /ha. in 6 month old sugarcane infested with woolly aphid

Replications: Five

Dipha aphidivora @ 1000/ ha was released in 3,4,5 and 6 months old woolly aphid infested crop infested. Fifteen days after release (DAR) of predator, there was no remarkable effect on woolly

Table 37. Field demonstration of bio control using *Dipha aphidivora* in two locations in Coimbatore

Treatment	Aphid population in 6.25 cm^2 area (90 DAR)		*Dipha* number / leaf	
	Puthur	Elyamuthur	Puthur	Elyamuthur
Dipha-released plot	12.5^a	19.0^a	2.6^a	2.3^a
Farmers field	86.7^b	74.2^b	1.2^b	0.8^b

Means followed by the same letter in a column are not significantly different (P=0.05)

aphid incidence in 3, 4, 5 and 6 month old sugarcane. Predator development of 0.57 larvae and pupae of predator / leaf was noticed within short period of 15 days in 6 month old sugarcane. The maximum predator development of 1.89 larvae and pupae / leaf was recorded in 6 month old sugarcane followed by 1.35 larvae and pupae / leaf in 5 month old sugarcane at 45 DAR. This resulted in reduction of woolly aphid incidence from 84.12 to 34.20/ 6.25 cm^2 at 45 days after release of predator and it further reduced to the 8.26/ 6.25 cm^2 at 60 DAR. Due to the development of predator, woolly aphid incidence was reduced from 65.38 to 45.26 at 45 days after release and further reduced to 7.14/ 6.25 cm^2 at 75 days after release. Sugarcane was free from woolly aphid incidence at 75 days after release in 6-month-old sugarcane and at 90 days at 5-month-old sugarcane. On 3- and 4-month- old sugarcane, predator establishment started late and peak of 0.89 and 0.78 larvae and pupae of predator/ leaf was noticed after 75 DAR. In 3 month old sugarcane, woolly aphid incidence was increased from 45.20 to 76.34 at 45 DAR and then reduced to 52.00 at 90 DAR. The time required for predator development and the subsequent woolly aphid reduction showed that above 5-month-old sugarcane is most suitable for faster predator establishment. In 3 and 4 month old sugarcane crop the predator development was also noticed above 5 months old crop.

(e) Field demonstration of biocontrol using *D. aphidivora* and *M. igorotus*

Two field demonstrations were conducted in the farmer's field at Puthur and Elayamuthur separated by 80 km. In one hectare of sugarcane field ten spots were selected and 1000 larvae of *D. aphidivora* were released therein, Another field with woolly aphid infestation was selected for comparison in which the farmer's practice was adopted. Initial aphid population and pest intensity rating as well as predators on leaf were observed in all the spots and @ 5 clumps / spot for both the plots. Subsequent observations were made on pest intensity and predator populations at 15 days interval. Farmers practice has the highest pest intensity rating (5), aphid population (85.6 and 73.3 per 6.25 cm^2 leaf area) and the lowest *D. aphidivora* population (1.1 and 0.9 per leaf) in Puttur and Elayamuthur, respectively. The results of the trial indicated that in *D. aphidivora* released plots the woolly aphid population was reduced substantially by 90 days and was totally suppressed by 120 days. The field efficacy of *D. aphidivora* or woolly aphid management with *D. aphidivora* was convincingly demonstrated (Table 37).

AAU (Navsari)

Multiplication of *M. igorotus* was done in woolly aphid-infested shadenet (30 sq. m). Shadenet-reared *M. igorotus* was evaluated in the woolly aphid-infested field at Sarbhon village of Bardoli sugar factory area. A total of 225 larvae of *M. igorotus* were released in two installments at weekly intervals. First release was made in the second week of June. The initial population density of aphid was 85.5 aphids/clump. The population of aphid came down to 68.5 aphids/ 6.25 cm^2 a week after release. Second release was made 15 days after first release. The aphid population remained low in the following two weeks (56.3 and 47.8 aphids/ 6.25 cm^2). However, the aphid population increased in the next week with 58.1 aphids/ 6.25 cm^2. The major problem in establishment of the predator was attributed to the high temperature.

The population of *D. aphidivora* was not observed in sugarcane white woolly aphid infested fields.

MPKV

To evaluate the potential of *D. aphidivora* under field conditions, a trial was laid out on the

Table 38. Effectiveness of *Dipha aphidivora* against woolly aphid under field conditions

Treatment	Mean SWA rating (DAR)		Mean no. of SWA/6.25 cm² per leaf		Mean no. of *D. aphidivora*/ leaf (DAR)		Cane yield (t/ha)
	Initial	Final	Initial	Final	Initial	Final	
Release of *Dipha*	4.5	2.6[a]	54.6	29.1[a]	0.0	3.2[a]	120[a]
Farmer's practice	3.9	5.0[a]	40.7	83.8[a]	0.0	1.3[b]	108[b]
CV %		13.4		25.1		4.8	3.0

Means followed by the same letter in a column are not significantly different (P=0.05)

research farm of Agronomy Section, College of Agriculture, Pune. The planting of sugarcane (cv. Co 94012) was done over 1 ha area divided into 2 blocks and each block was further sub-divided into 12 sectors. As per the experimental protocol, inoculative release of *D. aphidivora* @ 1,000 larvae in 10 spots per ha was carried out in the predator release block, whereas the predators were not released in farmer's practice block. The results revealed that inoculative release of *D. aphidivora* @ 1,000 larvae/ ha at 10 spots effectively reduced the woolly aphid population within 60 days and increased the cane yield significantly as compared to farmer's practice (Table 38).

(f) Life table studies of woolly aphid and its predators

MPKV

To know the age survival, age-specific reproduction, net reproductive rate, intrinsic rate of increase, stable age distribution and life expectancy as well as life-fecundity tables were studied for *C. lanigera* using sugarcane as a host under field conditions at College of Agriculture, Pune from October to December, 2006. Ten apterous adults of *C. lanigera* were released per leaf on 10 tagged sugarcane plants for settlement and deposition of nymphs. After deposition of 10 nymphs per leaf, all the adult females were removed. In all, 100 freshly deposited nymphs on 10 plants were kept under observation. The observations on nymphal instars, duration of each instar, adult development, adult longevity and reproduction and age-specific mortality in different life stages of *C. lanigera* was made daily. The age-specific reproduction was determined from the production of nymphal colony by the surviving adult females (apterous) developed on the same leaf. The life-tables were constructed for *C. lanigera* using the method proposed by Atwal and Bains (1974) on the following criteria.

1. x - Pivotal age in days
2. l_x - Survival of females at age x
3. m_x - Age schedule for female births a t age x
4. Calculated values of x, l_x and m_x obtained from life cycle data

Age-specific survival and reproduction rate of female:

The data regarding the survival and reproduction rate in accordance with age of females of *C. lanigera* are presented in Table 39. The maximum duration of nymphs and adults was 19 and 11 days, respectively. The average deposition of nymphs was 95.5 per female in 11 days of longevity. The successful survival from nymph to adult was 52 %. The deposition of nymphs commenced from 22nd day of pivotal age and continued up to 29th day. The rate of production (m_x as female offsprings) was found to increase steadily from 492 (22nd day) to 1055 (26th day). The mortality of females started from 29th day of the pivotal age.

Innate capacity of increase in numbers

It could be seen from Tables 66 and 67 that the mean corrected generation time (T^c) of *C. lanigera* was 25.0 days. The innate capacity (r^m) and finite rate (λ) for increase in numbers were 0.33 and 1.39 nymphs per female per day, respectively. At this rate, the population of *C. lanigera* was capable to multiply 10.1 times per week under the set of conditions. It took 0.498 days to multiply the population in 2 folds.

Table 39. Calculations of life-table studies of *Ceratovacuna lanigera*

Parameters	Formula / Calculations
Net reproductive rate (R_0)	$\Sigma L_x m_x$ = 2579.73 nymphs / 52 females i.e. 49.6 nymphs /female
Mean length of generation (T^c)	$\frac{\Sigma_x l_x m_x}{R_o}$ = 25.02 days
Innate capacity for increase in numbers (r^c)	$\frac{\log_e (R_o)}{T_c}$ = 0.31 nymphs / female /day
Arbitrary r^c	0.31, 0.32 and 0.33
Corrected r^m	$\Sigma e^{7\text{-}rm}{}_x l_x m_x$ =1096.6 R_m = 0.3300 nymphs / female /day
Corrected generation time	$\frac{\log_e (R_o)}{r_m}$ = 23.80days
Finite rate of increase in numbers (λ)	Antilog $e(r_m)$ = 1.3910 nymphs per day.
Weekly multiplication of population	$(e^{rm})7 = (1.3910)7$ = 10.08
Doubling time (DT)	$\frac{\text{Log}_e (2)}{\text{Log}_e \lambda}$ = 0.498 days

Stable age distribution

The stable age distribution of *C. lanigera* was worked out by observing the population schedule of birth and death rates (m_x and l_x) under given set of conditions. Nymphs and adults accounted for 91.4 and 0.02 %, respectively. Thus, the major contribution was made by immature stages as compared to adult stage to the population of stable age of *C. lanigera*.

Life expectancy

The perusal of data revealed that when the mortality range was at age interval of 15-20 days, the life expectancy was reduced to 1.88 days from 2.13 days.

(g) Identification of sugarcane variety susceptible for colonization of woolly aphid

TNAU

The sugarcane cv. CoC (sc) 23 was received from Sugarcane Research Station, Cuddalore, Tamil Nadu and it was compared with the locally promising cv. Co 86032. The varieties were planted during January 2007 in micro plots of 4x4m covered under shade net. A local variety highly susceptible to the pest was grown as border rows to serve as inoculum source. Field-collected woolly aphid was released @ 100/plant at weekly interval starting from 45 DAP. Sixteen such releases were made in both the varieties and the observations on woolly aphid colonization and leaf infestation were recorded at an interval of 14 days. The results indicated that there was no colonization and leaf infestation in the sugarcane variety CoC (sc) 23 even after 16 releases of woolly aphid as against in Co 86082 where12.7 (after 2nd release) to 67.7 (after 16th release) per cent leaves were infested with woolly aphid.

IISR

Planting of cane at wider row space (45:120 cm) proved superior to the conventional planting (75 cm distances) to minimize the intensity of *C. lanigera* infestation. With the help of cane development workers of sugar mills and farmers conservation of natural enemies and redistribution of the predators from high density area to low density area proved successful around Khatauli Sugar Mills areas of Uttar Pradesh.

(h) Colonization of *E. flavoscutellum*

TNAU

The parasitoid, *E. flavoscutellum* obtained from Assam by PDBC was brought to Coimbatore and 20 pairs were released in three hot spot areas for woolly aphid, in 2005. Three releases were

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Net reproductive rate (R_0)	$\Sigma L_x m_x$ = 2579.73 nymphs / 52 females i.e. 49.6 nymphs /female
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Innate capacity for increase in numbers (r^c)	$\frac{\log_e (R_0)}{T_c}$ = 0.31 nymphs / female /day
Arbitrary r^c	0.31, 0.32 and 0.33
Corrected r^m	$\Sigma e^{7-rm}{}_x l_x m_x$ =1096.6 R_m = 0.3300 nymphs / female /day
Corrected generation time	$\frac{\log_e (R_0)}{r_m}$ = 23.80days
Finite rate of increase in numbers (λ)	Antilog $e(r_m)$ = 1.3910 nymphs per day.
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The stable age distribution of *C. lanigera* was worked out by observing the population schedule of birth and death rates (m_x and l_x) under given set of conditions. Nymphs and adults accounted for 91.4 and 0.02 %, respectively. Thus, the major contribution was made by immature stages as compared to adult stage to the population of stable age of *C. lanigera*.

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The parasitoid, *E. flavoscutellum* obtained from Assam by PDBC was brought to Coimbatore and 20 pairs were released in three hot spot areas for woolly aphid, in 2005. Three releases were

Table 40. Establishment of *Encarsia flavoscutellum* in Coimbatore

Location	No./ leaf		
	12 months	14 months	16 months
1	3.2	12.2	11.7
2	3.1	9.6	14.2
3	8.2	3.8	16.8
4	2.6	19.2	15.8

Mean total no/leaf, mean of 6 values

made. One batch was also released in TNAU campus. Weekly post release observations showed no establishment of *Encarsia* observation up to 6 months post release. However when the fields were monitored in September 2006, 11 months post release, *Encarsia* establishment was confirmed in all 4 locations. Encarsia adults could be obtained up to 3 kms away from release spots in all directions (Table 40.).

Thus the parasite has established well in Coimbatore district, where at any given point of time all cane stages can be found due to staggered planting. From Nov.2006-Mar 2007, the parasitoid colonies were released in 14 districts in Tamil Nadu at 41 locations during the course of roving survey. In all locations, there was good establishment.

Other centres

There was no establishment of *Encarsia flavoscutellum* in western UttarPradesh, Andhra Pradesh and Gujarat.

(i) Impact of *E. flavoscutellum* on woolly aphid population

VSI

T_1 Release of *E. flavoscutellum* @ 500 adult / 100 sq. m.

T_2 Unreleased sugarcane.

Replications: Five

Encarsia flavoscutellum was collected from the Athani area of Karnataka state and released in Pune and Baramati Location of Maharashtra district. Sugarcane woolly aphid population per 6.5 cm^2 was recorded on three leaves (top, middle and bottom) per cane and by selecting canes from 5 spots/ field. Observations on parasite population per leaf population was also recorded. Observations on woolly aphid and parasite was taken at 15 days interval.

Encarsia flavoscutellum was released on 7-month-old sugarcane (cv. Co 86032) heavily infested with woolly aphid at Pune and Baramati. It could complete its life cycle within 10 days and its establishment was recorded after 15 days of release in the pest-affected sugarcane plot. Maximum of 12.59 *E. flavoscutellum* adult/ leaf was noticed at 30 days after release and with decrease in woolly aphid population the *E. flavoscutellum* population started declining. No *E. flavoscutellum* development was noticed in the unreleased plot. In *E. flavoscutellum* released plot woolly aphid incidence was reduced from 91.48 to 22.46 woolly aphids/ 6.5 cm^2 at 45 days after release and two months after release the sugarcane was free from woolly aphid incidence. In control plot, woolly aphid incidence increased from 95.98 to 112.51 woolly aphids/ 6.5 cm^2 at 15 days after release.

(j) Monitoring and forecasting of woolly aphid

IISR

Observation on population of woolly aphid and its natural enemies in relation to abiotic factors were made at weekly intervals from ratoon crop (after first appearance of *C. lanigera* colony) having CoS 767 variety. Population counts of aphids/ 2.5 x 2.5 cm area were recorded. Maximum *C. lanigera* population was recorded up to 225.86 (nymphs + adults) / 2.5x2.5 cm infested leaf area and *D. aphidivora* population was recorded to be 5.81 larvae/ infested leaf during last week of January 2007. *D. aphidivora*, *M. igorotus*, *Metasyrphus confrator*, coccinellids and *Theridula angula* were observed feeding on *C. lanigera*.

Maximum temperature ($r = -0.235$, $P= 0.001$) and minimum temperature ($r = -0.106$, $P=0.001$) showed negative correlation with the *C. lanigera* population. Highly significant positive correlations were found between *C. lanigera* population and three natural enemies viz. *D. aphidivora* ($r = 0.277$,

Table 41. Correlation coefficient of *Ceratovacuna lanigera* with natural enemies and abiotic factors

SWA/ Predators	Max. Temp. (°C)	Min. Temp. (°c)	Avg. R.H.%	Rainfall (mm.)	*D. aphidivora* / Leaf	*M. igorotus*/ Leaf	*M. confrator* / Leaf
C. lanigera / 2.5x 2.5 cm. leaf	-0.235	-0.106	0.280	0.144	0.277	0.749	0.620
D. aphidivora / Leaf	-0.840	-0.091	0.594	0.146	1.00	0.575	0.782
M. igorotus / Leaf	-0.468	0.016	0.597	0.229	0.575	1.00	0.632
M. confrator / Leaf	-0.719	-0.169	0.468	0.124	0.782	0.632	1.00

Significant P = 0.001

Table 42. Incremental growth of sugarcane (cv. Co 7219) attacked in sixth month by woolly aphid during 2006-07

Fortnight after marking canes#	Incremental growth (cm)		
	Infested cane	Healthy cane	*t*-value
1	15.78	16.13	0.45ns
2	8.98	16.57	9.75***
3	6.06	8.28	4.73***
4	14.28	13.82	0.56ns
5	7.82	8.18	0.48ns
6	7.71	6.52	1.68ns
7	5.16	4.99	0.28ns

#*n*= 83

P=0.001), *M. igorotus* (r = 0.749, *P*=0.001 and *M. confrator* (r = 0.620, *P*=0.001). *C. lanigera* population was noticed to be positively correlated with Average R.H. and rainfall (r = 0.280, 0.001; r = 0.144, *P*= 0.001) (Table 41).

(k) Yield loss assessment

SBI

Incremental growth of sugarcane in woolly aphid infested and uninfested canes was assessed at fortnightly intervals in the susceptible cv. Co 7219. The difference was not significant between infested and uninfested canes in the first fortnight after marking the canes. In the next two observations incremental growth was significantly lower in infested canes whereas in the subsequent observations the differences became non-significant (Table 42). These non-significant differences coincided with the rapid decline in aphid populations by the fourth fortnight and complete disappearance in the fifth fortnight owing to the buildup of *D. aphidivora* and *E. flavoscutellum* populations.

Analysis of cane and juice parameters indicated that cane weight, sucrose and purity did not differ between infested and uninfested canes. Jaggery analysis showed no significant differences in brix, sucrose and purity. In both juice and jaggery, reducing sugars were slightly lower in infested canes.

IISR

Quantitative and qualitative losses were worked out from the severely infested canes of CoS 8432, CoS 767, CoPt 84212, CoS 8436 CoJ 64, and CoS 88230 varieties. Along with severely *C. lanigera* infested canes, healthy canes from the same fields were also taken. Sample size was of 10 canes in 3 replications. Per cent loss in sugar recovery and weight ranged from 9.28 (CoS 8436) to 18.44 (CoS 767) and 10.54 (CoS 8436) to 19.75 (CoS 767), respectively (Table 43).

(l) Assessment of activity of *Micromus* in relation to abiotic factors (PDBC: to examine the data on population dynamics provided by centres and arrive at the effect of abiotic factors on *Micromus* activity)

Rainfall, temperature and RH did not correlate significantly with population levels of *M. igorotus* in Karnataka (PDBC).

Table 43. Losses caused by *Ceratovacuna lanigera* during 2006-07

Variety	Healthy canes			Infested canes		
	Recovery (%)	Weight (kg)	Recovery (%)	Weight (kg)	Loss in recovery (%)	Loss in weight (kg)
CoS 8432 (P)	10.9	8.3	9.1	7.4	16.3	11.3
CoS 767 (P)	10.3	8.0	8.4	6.4	18.4	19.8
CoPt 84212 (P)	10.3	8.9	9.0	7.5	12.7	15.8
CoS 8436 (P)	10.8	9.9	9.8	8.8	9.2	10.5
CoJ 64 (P)	10.7	7.9	8.8	7.0	18.2	10.8
CoS 88230 (P)	10.7	9.4	8.7	8.0	18.2	14.4

5.3 BIOLOGICAL SUPPRESSION OF COTTON PESTS

(i) BIPM for *Bt* cotton

Multi-location experiments were conducted during the year 2006-07 to evaluate the biocontrol based-IPM (BPIM) package for the management of pests and disease in *Bt* cotton. The following four modules were tested in 0.2 ha each.

Module I: BIPM + *Bt* Cotton

It consisted of recommended agronomic practices and application of FYM @ 25 tonnes /ha at the time of preparation of land; Seed treatment with *Trichoderma viride* (5g /kg seed); Border crop of maize; Release of 3 day old larvae of *C. carnea* @ 14,000 /ha once at initial aphid build up stage; Spray of *Sl* NPV @ 3x10 ^{12} POBs /ha, for *S. litura*. Application of *Sl* NPV mixed with 0.5% crude sugar as UV protectant and surfactant, when larvae are within 3^{rd} stage. Sowing non *Bt* cotton as refugia as recommended; Erection of bird perches @ 10/ha.

Module II: BIPM + non-*Bt* Cotton

It consisted of recommended agronomic practices and application of FYM @ 25 tonnes /ha at the time of preparation of land; Seed treatment with *T. viride* (5g /kg seed); Border crop of maize; Release of 3-day-old larvae of *C. carnea* @ 14,000 /ha once at initial aphid build up stage; Release of *T. chilonis* @ 1,50,000/ha/week synchronizing with appearance of bollworm (6-8 releases as per pest incidence); Application of *Bt* @ 1.0 kg/ha when any one of the bollworms is seen. Application of *Ha* NPV @3x10^{12} POBs /ha mixed with 0.5% crude sugar as UV protectant and surfactant against 1^{st} to 3^{rd} instar larval stage of *H. armigera*. Spray of *Sl* NPV @ 3x10^{12} POBs /ha for *S. litura*. Application of *Sl* NPV mixed with 0.5% crude sugar as UV protectant and surfactant, when larvae are in 1^{st} to 3^{rd} stage. Erection of bird perches @ 10/ha.

Module III: Standard practice (SP) + *Bt* cotton

It consisted of Following of recommended agronomic practices and application of FYM @ 25 tonnes /ha at the time of preparation of land; Seed treatment with Gaucho for sucking pests; Spray 1-2 systemic insecticides based on occurrence of sucking pests after 45 days of germination. Spraying of recommended insecticides for bollworms, if population exceeds ETL; Sowing of non *Bt* cotton as *refugia* as recommended.

Module IV: SP + non-*Bt* Cotton

It consisted of Gaucho-treated seeds; Local practice by farmers was also advocated.

ANGRAU

The experiment was laid out at the Agricultural Research Station, Warangal during *Kharif* 2006.

Overall results regarding the sucking pest incidence has suggested that the sucking pest population was more in *Bt* cotton + SP, while the populations were effectively suppressed in *Bt* cotton + BIPM module suggesting the impact of BIPM in suppressing the sucking pest complex which otherwise was found to be more prevalent in *Bt* cotton as compared to non *Bt* cotton. The damage caused by boll worms in *Bt* cotton

Table 44. Impact of bio-intensive pest management in *Bt* cotton

Treatment	Sucking pests/ 5 plants			Mean damage (%)			Yield (kg/ha)
	Aphids	Thrips	Jassids	White flies	Squares	Bolls	
Bt cotton + BIPM	37.2^{b}	22.4^{c}	21.6^{b}	2.9^{b}	5.2^{a}	6.2^{a}	2943^{a}
Non-*Bt* cotton + BIPM	32.7^{a}	9.6^{a}	16.8a	1.3a	20.4^{c}	17.1^{c}	2172^{b}
Bt cotton +SP	52.8^{d}	27.6^{d}	48.3c	32.7^{d}	7.7^{b}	8.1^{b}	2235^{b}
Non-*Bt* cotton + SP	49.6^{c}	14.1^{b}	22.1c	29.1^{c}	29.5^{d}	19.3^{d}	1986^{c}

Means followed by the same letter in a column are not significantly different (P=0.05)

in different modules gave a clear indication that the *Bt* cotton both under BIPM conditions as well as in SP conditions were effective in minimizing the damage.

Maximum egg parasitism of 3.7% was noticed in non-*Bt* cotton + BIPM followed by 1.55 in *Bt* cotton + BIPM. In Standard Practice the per cent egg parasitism was minimal irrespective of the type of cotton grown. As far as Coccinellids are concerned a maximum of 24.3 per 50 plants were noticed in non-*Bt* cotton + BIPM followed by 21.7 per 50 plants in *Bt* cotton + BIPM. Similar trends were noticed in the case of spider fauna also with maximum of 25.2 per 50 plants noticed in non *Bt* cotton with BIPM followed by 20.7 per 50 plants in *Bt* cotton + BIPM. The populations were as low as 0.6 and 0.3 for Coccinellids and spiders respectively in non-*Bt* cotton + SP module.

The overall picture is that the natural enemy activity was more in the modules consisting of BIPM while there was minimal natural enemy activity in the modules consisting of the SP irrespective of the type of cotton grown. Highest yield (2943 kg / ha) was recorded in *Bt* cotton+ BIPM with CB ratio of 6.4 followed by *Bt* cotton+ FP resulting into 2235 kg / ha with CB ratio of 3.6. *Bt* cotton + BIPM hosted least boll worms with minimum square and boll damage and recorded maximum natural enemy activity as well as yield and better net returns to the farmers (Table 44).

AAU(A)

The experiment was laid out at the Agronomy Farm, B. A. College of Agriculture, Anand during *Kharif* 2006 on RCH-2 *Bt* cotton.

The data (Table 45) revealed that there was reduction in sucking pest population in case of *Bt* cotton + BIPM package and *Bt* cotton + recommended package of practices as compared to non-*Bt* cotton + standard package of practices. *Bt* cotton + BIPM package recorded significantly lower bud (0.8%) and green boll (0.9%) damage in comparison to the rest of the treatments. Non-*Bt*

Table 45. Impact of BIPM on the incidence of insect pests and yield of *Bt* cotton at Anand

Treatment	Sucking pests / 15 leaves			Bollworm damage (%)				Yield (kg)
	Aphids	Leaf hoppers	White flies	Bud	Boll	Locules		
						E. v.	*P. g.*	
Bt cotton + BIPM	14.1^{d}	2.0^{d}	2.1^{d}	0.8^{c}	0.9^{c}	0.8^{b}	0.8^{c}	2544^{a}
Non- *Bt* cotton +BIPM	28.7^{b}	3.9^{b}	4.0^{b}	4.2^{b}	5.6^{b}	11.0^{a}	22.1^{a}	2028^{b}
Bt cotton + recommended package of practices	19^{c}	2.8^{c}	3.0^{c}	1.2^{c}	1.5^{c}	1.0^{b}	1.2^{b}	2375^{a}
Non-*Bt* cotton + GAU schedule	34.9^{a}	6.0^{a}	5.8^{a}	6.1^{a}	7.4^{a}	11.8^{a}	23.6^{a}	1922^{b}

Figures in table are original values. *E.v.*= *Earias vittella*, *P. g.* = *Pectinophora gossypiella*

Means followed by the same letter in a column are not significantly different (P=0.05)

cotton + GAU schedule exhibited 6.1 and 7.4% bud and boll damage respectively. Locule damage due to *Earias vittella* and *Pectinophora gossypiella* (0.8%) was also found to be low in *Bt* cotton + BIPM package, whereas it was 11.8 and 23.6% respectively in case of non-*Bt* cotton + GAU schedule. *Bt* cotton + recommended package of practices recorded 1.2 and 1.5% bud and boll damage respectively, while locule damage due to *E. vittella* and *P. gossypiella* was 1.0 and 1.2%, respectively (Table 45).

Seed cotton yield was significantly high in *Bt* cotton + BIPM package (2544 kg/ha.) as well as *Bt* cotton + standard package of practices (2375 kg/ha.) as compared to the other two treatments under evaluation.

Relatively high population of different natural enemies were recorded in the treatment of *Bt* cotton + BIPM package and non-*Bt* cotton + BIPM package compared to the other two treatments indicating detrimental effects of the insecticides used. Maximum parasitism of *T. chilonis* was found in non-*Bt* cotton + BIPM package (25.1%) followed by *Bt* cotton + BIPM package (17.1%) (Table 46).

TNAU

The experiment was laid out at Puthur, Coimbatore during *Kharif* 2006 - 2007. The incidence of leafhoppers in different modules ranged between 2.2 to 5.0 per plant. The *Bt* cotton with the adoption of standard practice recorded the lowest incidence of hoppers followed by *Bt* with BIPM module (Table 47).

The mean number of aphids in different modules ranged from 2.2 to 5.1 per plant, the least being recorded in *Bt* with SP module. A similar trend was observed with reference to the population of thrips and white flies. The BIPM modules recorded significantly higher number of natural enemies than the SP modules.

Natural enemies

The coccinellids which were predominant during the field studies were *Menochilus sexmaculatus* Fab. and *Coccinella transversalis* Fab.. The order of occurrence of coccinellids in the different modules was *Bt* BIPM > non-*Bt* BIPM > non-*Bt* SP > *Bt* SP. Significantly more number of *Chrysoperla* larvae were recorded in *Bt*-BIPM than in other plots. The occurrence of spiders was higher in BIPM modules than in SP modules. The frequently observed spiders in the present study were *Oxyopes* spp., *Argiope* spp., *Neoscona* spp., *Araenus* spp. and *Plexippus* spp.

Table 46. Impact of BIPM in *Bt* cotton on the population of natural enemies at Anand

Treatment	Mean population of natural enemies per 25 plants					Parasitisation
	C. carnea	*C. sexmaculata*	Geocoris	Staphylinids Adult	Rogas Cocoon	by *T. chilonis*
Bt cotton+ BIPM package	74.2	66.3	28.3	5.0	5.7	17.1
Non-*Bt* cotton +BIPM package	68.0	59.5	24.3	4.3	5.3	25.1
Bt cotton + existing package of practices	65.2	47.3	18.2	4.2	1.3	15.7
Non-*Bt* cotton + GAU SP	55.8	42.3	16.0	3.7	0.8	14.

Table 47. Incidence of sucking pest population in different modules at Puthur during 2006-2007

Module	Mean number of insects/plant					
	Leafhoppers	Aphids	Thrips	Whiteflies	*Chrysoperla*	Coccinellids
Bt – BIPM	2.8^{b}	2.7^{b}	0.3^{b}	1.0^{b}	0.41^{a}	3.00^{a}
Non-*Bt* – BIPM	3.0^{c}	2.8^{c}	0.4^{c}	1.1^{c}	0.30^{b}	1.32^{b}
Bt – SP	2.2^{a}	2.2^{a}	0.0^{a}	0.5^{a}	0.22^{a}	0.16^{d}
Non-*Bt* – SP	5.0^{d}	5.1^{d}	1.0^{d}	1.7^{d}	0.07^{d}	0.61^{c}

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 48. Incidence of bollworms and damage in different modules at Puthur (2006 -2007)							
Modules	No. of larvae / plant		Bollworm damage (%)				Yield
	H. armigera	*E. vitella*	Fruiting bodies	Open boll	Locule	Inter locule	(Kg/ha)
Bt – BIPM	0.10^{a}	0.03^{a}	1.10^{a}	0.4^{a}	0.18^{a}	0.23^{a}	1960^{a}
Non *Bt* – BIPM	0.30^{c}	0.11^{b}	2.40^{c}	0.8^{c}	0.61^{c}	0.87^{c}	1685^{c}
Bt – SP	0.20^{b}	0.04^{a}	1.50^{b}	0.6^{b}	0.24^{b}	0.29^{b}	1900^{b}
Non *Bt* – FP	0.70^{d}	0.60^{c}	4.80^{d}	1.8^{d}	1.41^{d}	1.45^{d}	1488^{d}
Means followed by the same letter in a column are not significantly different (P=0.05)							

Table 49. Effect of bio-intensive pest management practices on pest complex, natural enemies and yield of *Bt* cotton during 2006-07 at College of Agriculture, Dhule									
Treatment	Sucking pest population/ 3 leaves				NEs population (No. / plant)		Bollworm damage (%)		Yield of kapas
	Aphids	Jassids	Thrips	Leaf miner	Coccinellids	*C. carnea*	Squares	Bolls	(kg/ha)
Bt cotton with BIPM package	50.8	16.2^{c}	3.4^{b}	2.6	3.7	2.1^{a}	0.0^{a}	4.6^{b}	2400
Non *Bt* cotton with BIPM package	46.0	12.5^{c}	4.2^{b}	3.2	3.9	1.4^{b}	2.5^{b}	3.2^{a}	2500
Bt cotton with standard package	43.0	7.2^{b}	1.2^{a}	3.8	3.6	2.4^{a}	0.0^{a}	2.6^{a}	2450
Non *Bt* cotton with standard practice	41.0	2.1^{a}	1.2^{a}	3.8	3.5	1.2^{b}	10.2^{c}	3.2^{a}	2160
Means followed by the same letter in a column are not significantly different (P=0.05)									

Bollworm damage

The per cent fruiting body damage in different modules was in the order of *Bt* BIPM < *Bt* SP < Non *Bt* BIPM < non-*Bt* SP. Similar trend was noticed in case of open boll, locule and inter locule damage (Table 48). Hence the *Bt*-BIPM plots recorded lowest number of bollworms and lowest extent of damage.

Yield

The *Bt* cotton protected with IPM module recorded more yield (1960 kg / ha), whereas non-*Bt* SP module recorded 1488 kg / ha. *Bt* cotton under BIPM or SP performed better in reducing the bollworm damage and gave higher seed cotton yield.

MPKV

The data on sucking pests revealed no significant differences in population of aphids and leaf miners between the treatments. Population of leaf hoppers and thrips were higher in BIPM (both *Bt* and non-*Bt*) than in standard practice (Table 49). *Bt* cotton recorded higher population of coccinellids than non-*Bt* cotton. Since the damage to squares and bolls were very low and the differences in seed cotton yield being not significant no meaningful conclusion can be drawn.

PAU

The experiment on BIPM of *Bt* Cotton was conducted at Karni Khera (District Ferozepur) by taking three *Bt* and three Non- *Bt* hybrids namely RCH 134 *Bt*, MRCH 6301 *Bt*, Ankur 651 *Bt*, RCH 134 Non-*Bt*, MRCH 6301 non-*Bt* and Ankur 651 non-*Bt* during *Kharif* 2006-2007. The data revealed that population of white flies, jassids on *Bt* hybrids was marginally lower in BIPM plots than the non-*Bt* BIPM plots. There were, however, no significant differences in the spider population in both non-*Bt*

Table 50. Pest incidence in BIPM of *Bt* cotton at village Karni Khera, Punjab during 2006.												
Organism/ 3 leaves	Insect number / 3 leaves											
	RCH 134				MRCH 6301				Ankur 651			
	Bt		Non-*Bt*		*Bt*		Non-*Bt*		*Bt*		Non-*Bt*	
	SP	BIPM	SP	BIPM	SP	BIPM	SP	BIPM	SP	BIPM	SP	BIPM
Leafhopper	2.3	1.6	2.1	2.0	2.1	2.3	2.1	1.8	2.1	1.9	2.4	1.9
Whitefly	1.9	1.8	1.6	1.7	1.6	2.0	1.9	1.8	2.1	2.0	2.3	1.9
Spider	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Predators	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.2
Seed cotton (kg/ha)	3510	3420	3150	3090	3020	3010	2850	2710	2400	2220	2050	2000

Table 51. Status of pest complex in different *Bt* cotton hybrids and their non-*Bt* counterparts in Warangal district							
Cultivar	Sucking pests/3 leaves			Damage by bollworms (%)			Seed cotton yield (kg/ha)
	Aphids	Jassids	WF	Square	Boll	Locule	
RCH 2 *Bt*	5.8^{b}	7.1^{b}	10.1^{b}	6.4^{f}	1.2^{h}	19.2^{g}	3174^{a}
RCH 2 non-*Bt*	2.3^{h}	3.6^{d}	7.2^{d}	21.3^{b}	7.2^{d}	22.1^{c}	2651^{b}
RCH 20 *Bt*	6.9^{a}	8.7^{a}	12.2^{a}	5.18^{g}	2.1^{f}	20.1^{f}	2723^{b}
RCH 20 non-*Bt*	5.7^{b}	4.2^{d}	8.1^{c}	19.1^{d}	8.42^{b}	25.6^{a}	2241^{c}
Bunny *Bt*	3.2^{f}	4.2^{d}	5.6^{e}	4.22^{h}	0.9^{i}	23.6^{c}	2862^{b}
Bunny non-*Bt*	2.9^{g}	3.6^{d}	4.2^{f}	20.4^{c}	6.7^{e}	22.7^{d}	2415^{c}
Mallika *Bt*	4.7^{d}	5.4^{c}	7.1^{d}	6.21^{f}	2.2^{f}	17.2^{h}	3267^{a}
Mallika non-*Bt*	4.2^{e}	3.9^{d}	5.7^{e}	22.1^{a}	7.8^{c}	19.1^{g}	2431^{c}
ProAgro 368 *Bt*	4.9^{d}	6.9^{b}	8.2^{c}	5.23^{g}	1.9^{g}	24.5^{b}	2837^{b}
ProAgro 368 non-*Bt*	5.2^{c}	5.2^{c}	3.5^{g}	18.7^{e}	9.2^{a}	25.6^{a}	1958^{d}
Means followed by the same letter in a column are not significantly different (P=0.05)							

hybrids. The population of predators (*C. carnea, Geocoris* sp., *Zelus* sp. and pirate bug) on *Bt* hybrids at Karni Khera on IPM and BIPM practices was 0.1 and 0.2 on RCH 134 *Bt* and MRCH 6301*Bt* and 0.1 and 0.1 on Ankur 651*Bt*. The mean population of predators on non-*Bt* hybrids at Karni Khera on standard practices and BIPM practice was 0.2 and 0.1 on RCH 134 non- *Bt*; 0.2 and 0.2 on MRCH 6301 non-*Bt* and 0.1 and 0.2 on Ankur 651 non-*Bt* (Table 50).

It can be concluded that the sucking pests on *Bt* as well as non *Bt* cotton can be managed by using only BIPM package. There was no significant difference in yield between the *Bt* and non-*Bt* hybrids as the pest population was low, however, highest yield was recorded in RCH 134 *Bt* followed by MRCH 6301 *Bt* and Ankur 651 *Bt* hybrids.

(ii) Natural enemy complex of pests in *Bt* & non-*Bt* cotton varieties & hybrids

ANGRAU

The experimentation was taken up in Gorrupadu and surrounding villages of Warangal district. A total of 5 *Bt* cotton hybrids, viz. RCH-2 and 20, Bunny, Mallika and ProAgro-368 were observed for the incidence of sucking pests, damage of boll worms, extent of parasitism by *T. chilonis*, abundance of predatory fauna such as chrysopids, coccinellids, predatory bugs and spiders and yield of seed cotton during the experimentation. The data from the non-*Bt* counter parts of the above *Bt* hybrids was also recorded for the purpose of comparisons.

Perusal of the data revealed that (Table 51 & 52) the *Bt* hybrids varied differently with their

Table 52. Abundance of natural enemies in different *Bt* cotton hybrids and their non-*Bt* counterparts in Warangal district

Cultivar	Mean populations of natural enemies/ 25 plants				Parasitisation by
	C. carnea	Coccinellids	Bugs	Spiders	*T. chilonis* (%)
RCH 2 *Bt*	19.2	22.7	12.3	9.2	1.9
RCH 2 non-*Bt*	21.7	14.5	7.5	8.7	18.7
RCH 20 *Bt*	22.5	17.2	8.9	14.5	2.3
RCH 20 non-*Bt*	17.7	15.4	9.1	12.7	19.4
Bunny *Bt*	16.5	27.9	16.2	18.5	1.7
Bunny non-*Bt*	21.2	23.4	14.7	16.4	14.3
Mallika *Bt*	12.8	19.8	13.8	8.9	2.5
Mallika non-*Bt*	19.7	25.6	9.2	10.2	21.2
ProAgro 368 *Bt*	22.6	14.2	12.7	12.3	1.8
ProAgro 368 non-*Bt*	18.4	18.1	9.4	14.2	15.5

Table 53. Population of natural enemies in different cotton cultivars (2006-07)

Treatment*	Mean population of natural enemies per 25 plants					Parasitisation
	C. carnea	*C. sexmaculatus*	*Geocoris* sp.	Staphylinids	*Rogas* sp.	by *T. chilonis* (%)
Bt with SD	76.7	65.8	27.8	8.0	2.2	15.4
Bt without SD	73.2	60.0	24.3	6.5	1.5	14.5
G-Cot H- 8	49.2	43.0	9.0	4.3	2.5	20.6
G Cot H-10	53.5	46.7	11.2	5.0	3.5	23.0

* SD= seed treatment with imidacloprid

non-*Bt* counterparts and also among themselves. Maximum number of aphids was recorded in RCH 20 *Bt* followed by RCH 2 *Bt* and minimum on Bunny non-*Bt* . Similarly, maximum number of leafhoppers was recorded in RCH 20 *Bt* and minimum on Bunny non-*Bt*. The whitefly incidence was maximum in RCH 20 *Bt* and minimum in ProAgro 368 non-*Bt* hybrid. The *Bt* hybrids harboured more sucking pests fared better in suppressing square and boll damage as compared to their non-*Bt* counterparts.

Maximum egg parasitism by *T. chilonis* (21.2%) was noticed in Mallika non-*Bt* followed by 19.4% in RCH 20 non-*Bt*. In *Bt* hybrids the overall egg parasitism by *T. chilonis* was found to be less, ranging from 1.7 – 2.5% . The abundance of chrysopids was maximum in ProAgro 368 *Bt* while the coccinellids were found to be more in Bunny *Bt*. The predatory bugs and spiders were also found to be maximum in Bunny *Bt*.

AAU(A)

The experimentation was taken up at the Agronomy Farm of B. A. College of Agriculture. RCH-2 *Bt* and G-cot H-8 and G-cot H-10 both non Bt hybrids were observed for the incidence of sucking pest, damage of boll worms, extent of parasitism by *T. chilonis,* abundance of predatory fauna such as chrysopids, coccinellids, predatory bugs and spiders and yield of seed cotton.

Population of natural enemies (Table 53) was relatively higher in *Bt* cotton irrespective of the seed treatment while a relatively lower population of various bioagents was recorded from both the local hybrid cultivars. Interestingly, higher parasitism in bollworm eggs by *T. chilonis* (20.6 to 23.0%) was recorded in non-*Bt* cultivars as against 14.4 to 15.4% in *Bt* cultivars.

Bt cotton seed treated with imidacloprid registered significantly lower incidence of sucking pests as compared to the other treatments evaluated. *Bt* cotton without seed treatment was found better than non-*Bt* cotton hybrids without seed treatment. Similar trend was observed with reference to bud and boll damage. *Bt* cotton (RCH-2) + imidacloprid seed treatment recorded minimum (0.8 to 0.9%) locule damage by *E. vittella* and *P. gossypiella*

Table 54. Incidence of insect pests and seed cotton yield in *Bt* and non *Bt* Hybrids (2006-07)

Treatment	Sucking pests / 15 leaves			Damage by bollworms (%)				Yield (kg/ha)
	Aphid	Jassid	Whitefly	Bud	Boll	Locules		
						E. v.	*P. g.*	
RCH 2-*Bt* with SD*	18.8^{d}	3.7^{d}	3.0^{d}	1.1^{d}	1.8^{d}	0.8^{c}	0.9^{b}	2483^{a}
RCH 2- *Bt* without SD*	30.7^{c}	7.9^{c}	4.4^{c}	2.2^{c}	3.4^{c}	1.2^{c}	1.2^{b}	2350^{a}
G Cot Hybrid 8	55.6^{a}	11.6^{a}	6.0^{a}	7.4^{a}	9.6^{a}	12.3^{a}	21.8^{a}	1683^{b}
G Cot Hybrid 10	52.3^{b}	10.2^{b}	5.3^{b}	6.1^{b}	7.7^{b}	10.6^{b}	20.8^{a}	1903^{b}

E.v.= Earias vittella, P. g.= Pectinophora gossypiella

*SD= seed treatment with imidacloprid

Means followed by the same letter in a column are not significantly different (*P*=0.05)

whereas it was 1.2% in case of *Bt* cotton without seed treatment. However, both the treatments were at par with each other (Table 54). Maximum seed cotton yield was harvested in *Bt* cotton + imidacloprid seed treatment followed by *Bt* cotton without Gaucho seed treatment. Both the treatments registered higher yields over non-*Bt* cultivars.

PAU

The experiment was conducted at the Entomological Research Farm, PAU, Ludhiana. Four *Bt* hybrids namely MRCH 6301, MRCH 6304, RCH 134, RCH 317 and their non-*Bt* counterparts were grown in a plot size of 500 m^2 each with three replications.

When data was pooled the highest jassid population (1.0 nymph/ 3 leaves) was recorded in MRCH 6301 *Bt* and it was significantly higher than all other cultivars except RCH 134 (non-*Bt*) and RCH 317 (non-*Bt*). Lowest population (0.3 nymphs/ 3 leaves) was recorded in RCH 317 *Bt* and it was significantly lower than RCH 134 (non-*Bt*) and MRCH 6301*Bt* but on par with other cultivars (Table 55).

The whitefly population remained low during the season with no significant differences among various cultivars. The *Bt* cultivars remained free from bollworm incidence. However, on non- *Bt* hybrids, the incidence of spotted bollworms was recorded. *H. armigera* did not appear during the season. The incidence of spotted bollworm among the intact fruiting bodies varied significantly among the cultivars on all the dates of observations. When data of all dates were pooled, the bollworm incidence in non-*Bt* hybrids (15.0 to 18.2%) was significantly higher than *Bt* hybrids where incidence

Table 55. Occurrence of pests and their natural enemies in different *Bt* and non-*Bt* hybrids of cotton in Punjab

Treatment	Number/ 3 leaves			
	Leaf hoppers	Whiteflies	Square damage (%)	Yield (kg/ha)
RCH 134 *Bt*	0.4^{ab}	1.0	0.0^{a}	2860^{a}
RCH 317 *Bt*	0.3^{a}	0.7	0.0^{a}	2530^{b}
RCH 134 Non-*Bt*	0.9^{bc}	1.1	16.8^{c}	1960^{d}
RCH 317 Non-*Bt*	0.7^{abc}	0.7	18.2^{d}	1740de
MRCH 6304 *Bt*	0.4^{ab}	0.9	0.0^{a}	1680^{e}
MRCH 6304 Non- *Bt*	0.4^{ab}	1.6	15.0^{b}	2280^{c}
MRCH 6301Non- *Bt*	0.4^{ab}	0.9	16.5^{c}	1520^{f}
MRCH 6301 *Bt*	1.0^{c}	1.6	0.0^{a}	2260^{c}

Means followed by the same letter in a column are not significantly different (*P*=0.05)

was nil. Among Non *Bt* hybrids, lowest incidence was recorded in MRCH 6304 (non-*Bt*) and it was significantly lower than other non-*Bt* hybrids. Significantly higher incidence was recorded in RCH 317 (non-*Bt*) than all other cultivars.

Incidence of spotted bollworms among green bolls was also recorded only on non- *Bt* hybrids and *Bt* hybrids were free from its attack. Among the non-*Bt* hybrids there was no significant difference in bollworm incidence among green bolls and it varied from 6.0 % to 6.3 %. Population of natural enemy complex including *Chrysoperla* spp., *Zelus* spp. *Geocorus* spp. and spiders varied from 0.8 to 0.9 per plant and there was no significant difference among various cultivars.

The yield of seed cotton in *Bt* hybrids was significantly higher than non-*Bt* hybrids. The highest yield was recorded in RCH 134(*Bt*) and it was significantly higher than all other cultivars. The lowest yield was recorded in MRCH 6301 (non-*Bt*) and it was significantly lower than all other cultivars except- MRCH 6304 (non-*Bt*) and RCH 317(non-*Bt*).

(iii) Enhancement of natural enemy population in cotton by habitat manipulation

PAU

The experiment on enhancement of natural enemy population in cotton by habitat manipulation was conducted at Entomological Farm, PAU, Ludhiana.

The following three module (M) were tested:

M_1 - **Habitat management**: Four paired rows of cotton interspersed with one paired row consisting of one row of cowpea and one row of marigold. One paired row of sorghum was grown all- round the plot as border crop. Eight releases of *T. chilonis* @150000 / ha were made at weekly interval coinciding with egg laying by boll worm from July to October.

M_2 - **BIPM practice**: Twelve releases of *T. chilonis* @1,50,000/ha at weekly interval from July to October. Since, *H. armigera* and *S. litura* did not appear on the crop, no NPV spray was given.

M_3 - **Insecticidal control**: One spray of imidacloprid 200SL @100ml/ha on 30-8-06 for the control of cotton jassid. One spray of decamethrin 2.8EC @ 400ml / ha on 9-8-06 and second of endosulfan 35 EC @ 2.5l / ha on 16.9.06 against spotted bollworm (*Earias* sp.).

The data revealed that leaf hopper population was significantly lower (1.8nymphs/ 3leaves) in the insecticidal control plot as compared to habitat management and BIPM plots. The white fly remained below ETL (18 adults/ 3leaves) and the mean whitefly population did not vary significantly among the treatments (Table 56). There was no incidence of *H. armigera* and *S. litura* on cotton during 2006. However, spotted bollworm appeared as an important pest and its incidence was significantly lower in insecticidal treatment plot than habitat management and BIPM. Bollworm incidence in habitat management was on par with BIPM (Table 56).

Similarly significantly lower bollworm incidence and boll damage among green bolls was recorded in insecticidal control plot than habitat

Table 56. Effect of crop habitat diversity on the occurrence of pests and natural enemies population in cotton in Punjab during 2006

Treatment	population/ three leaves		Square damage (%)	Yield (kg/ha)	Natural enemy per plant	Yield (kg/ ha) 2005-06 pooled	Mean natural enemy per plant (2005-06 pooled)
	Leaf hoppers	Whitefly					
Habitat management	4.9^b	1.9	10.6^b	1080^b	1.2	1100b	1.0
BIPM	4.9^b	2.2	11.4^b	1010^b	1.0	1060b	0.8
Insecticidal control	1.8^a	1.6	6.6^a	1290^a	0.1	1390a	0.1

Means followed by the same letter in a column are not significantly different (P=0.05)

management and BIPM, the latter two being on par (Table 56). Natural enemies population consisting of *Chrysoperla* sp.; *Zelus* sp., *Geocoris* sp., and spiders was higher in habitat management plot followed by BIPM and was lowest in insecticidal control (Table 56). Highest seed cotton yield was was recorded in insecticidal control plot and it was significantly higher than habitat management and BIPM the later two being on par (Table 56).

ANGRAU

The experiment was laid out at ARS, Warangal during *Kharif* 2006-07. The following crop habitat module (M) were maintained for the purpose of experimentation.

M1: - Four paired rows of cotton interspersed with one paired row consisting of cowpea and one row of marigold. Al round the plot, one paired row of sorghum was raised as border crop. Single release of *C. carnea* @ 5000/ha was made synchronizing with appearance of sucking pests and release of *T. chilonis* @ 1,50,000/ha/week was done coinciding with egg laying by boll worm. Three such releases were made.

M2: - Cotton without intercrop/border crop was maintained under BIPM practices

M3: - Cotton without intercrop/border crop was maintained with Farmer's practices (FP).

The results of the expeiment revealed that maximum number of aphids, leaf hoppers and white flies were noticed in M3, while minimum was noticed in M1, where the cotton was interspersed with cowpea and marigold with a border row of jowar (Table 57.). Least square and boll damage was recorded in Module M 1 while maximum square and boll damage was recorded in M3 where cotton was grown with farmer's Practice module.

Maximum egg parasitism by *T. chilonis* and more number of predatory fauna of chrysopids, coccinellids, predatory bugs and spiders were noticed in M1 module while these predatory populations were least in M3 where cotton was grown under farmer's practice module with chemical pesticides (Table 58). Seed cotton M1 also recorded maximum seed cotton yield of 2326 kg/ ha while M2 recorded 1025 kg/ha. In M3 where cotton was grown under farmer's practice module minimum yield of 1158 kg/ha was recorded.

Results of the experimentation has proved that when cotton was grown interspersed with cowpea and marigold with a border row of sorghum there was enhancement in the population of natural enemies resulting in reduced levels of sucking pest populations and damage by boll worms with increased yields and net returns.

Table 57. Impact of crop habitat manipulation on the occurrence of pests on cotton in Andhra Pradesh

Crop module	Sucking pests/3 leaves			Damage by boll worms (%)			Yield
	Aphids	Jassids	WF	Square	Boll	Locule	(kg/ha)
Cotton+IC+BC	2.3^{a}	0.9^{a}	5.3^{a}	3.9^{a}	0.2^{a}	21.2^{b}	2326^{a}
Cotton+BIPM	4.9^{b}	3.4^{b}	8.5^{b}	4.2^{b}	1.9^{b}	20.3^{a}	1052^{b}
Cotton+FP	7.8^{c}	4.2^{c}	10.3^{c}	6.5^{c}	2.7^{b}	29.7^{c}	1158^{b}

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 58. Abundance of natural enemies in different crop habitat manipulation modules

Crop module	Mean Populations of natural enemies per 25 plants				Parasitism by *T. chilonis*
	C. carnea	Coccinellids	Bugs	Spiders	
Cotton+IC+BC	23.5	18.5	16.1	12.1	2.71
Cotton+BIPM	12.3	9.7	7.5	5.4	1.83
Cotton+FP	0.8	0.3	0.3	2.7	0.87

Table 59. Incidence of insect pests and yield of cotton under crop habitat diversity at Anand

Module	Sucking pests / 15 leaves			Damage by bollworms (%)				Seed cotton yield (kg/ha)
	Aphids	Leaf hoppers	Whiteflies	*E. vittella*		Locules		
				Bud	Boll	*E. v.*	*P. g.*	
1	13.4[d]	3.1[c]	2.7[c]	3.3[d]	5.9[d]	12.2[c]	12.8[d]	1969[a]
2	23.4[c]	5.0[b]	4.4[b]	4.9[c]	8.2[c]	13.0[c]	15.6[c]	1864[a]
3	26.4[b]	4.9[b]	3.2[c]	7.6[b]	10.7[b]	15.0[b]	23.6[b]	1781[a]
4 (control)	105.1[a]	12.6[a]	9.2[a]	18.0[a]	29.7[a]	31.3[a]	31.5[a]	1278[b]

E.v.= Earias vittella, P. g.= Pectinophora gossypiella
Means followed by the same letter in a column are not significantly different (P=0.05)

Table 60. Population of natural enemies in different treatments under habitat manipulation (Pooled of 2005-06 and 2006-07)

Module	Mean population of natural enemies/25 plants					Parasitism by
	C. carnea	*C. sexmaculatus*	*Geocoris*	*Staphylenids*	*Rogas*	*T. chilonis* (%)
1	68.7	61.0	24.8	7.0	3.2	17.8
2	40.1	51.2	21.0	5.4	2.5	14.4
3	15.9	16.7	8.5	2.4	1.0	5.1
4 (control)	21.4	42.5	14.9	4.3	1.9	10.7

AAU(A)

The experiment was conducted in agronomy farm, B. A. College of Agriculture, Anand. Agro-climatic zone-3 during the 2005-06. The following modules were evaluated:

M1: Treatment of cotton seeds with *Trichoderma* @ 5.0 g / kg, cotton interspersed with *Cassia occidentalis* (6:1) + 10 % planting of maize and zinnia + one round of *T. chilonis* @ 1,50,000 + 5000 larvae of *C. carnea* (one release).

M2 : Treatment of cotton seeds with *Trichoderma* @ 5..0 g / kg, cotton interspersed with *Cassia occidentalis* (6:1) + 10 % planting of maize and zinnia.

M3 : Insecticidal control

M4 : Untreated control

Data presented in Table 59 indicates that the sucking pest population was significantly low in M1 [IPM + *T. chilonis* + *C. carnea* (6:1)] as compared to the other treatments evaluated. Incidence of *E. vittella* on buds and bolls was also found to be lower in habitat manipulations. Maximum seed cotton yield (1969 kg/ ha.) was harvested from the plots with *Trichoderma* seed treatment + cotton interspersed with *C. occidentalis* + planting of maize and zinnia @ 10% + one release of biocontrol agents followed by IPM (6:1) treatment. Both the treatments produced significantly higher yields over untreated check (Table 59).

Greater numbers of natural enemies (Table 60) were recorded from M1 indicating beneficial effect of habitat manipulation. The parasitism of bollworm eggs by *T. chilonis* as well as the occurrence of predators were also higher in habitat manipulation treatments.

(iv) Kairomones to increase the efficiency of trichogrammatids

UAS(D), Raichur in collaboration with PDBC

This experiment was conducted on NCS-145 (Bunny cotton hybrid) at the Regional

Table 61. Incidence of *Helicoverpa armigera*, recovery of Trichogrammatids and seed cotton yield during *Kharif* 2006-07

Module	Recovery of *T. chilonis* (%)	Fruiting bodies damage (%)	Seed cotton yield (kg/ha)
1	19.55^{a}	14.25^{b}	1512^{ab}
2	28.79^{b}	12.90^{a}	1605^{a}
3	12.82^{c}	15.27^{bc}	1467^{bc}
4 - control	8.91^{d}	17.62^{c}	1395^{c}

Means followed by the same letter in a column are not significantly different (P=0.05)

Agricultural Research Station, Raichur with the following modules (M).

M1.Release of one Trichocard *(Trichogramma* parasitised *Corcyra* egg cards) which was cut into 16 bits and stapled on the cotton plants randomly.

2. After 8- 10 days of release of the trichogrammatids, tricosane-treated dispensers (32 in numbers) along with the *Corcyra* egg card cut into 32 bits and placed on the 32 plants. Dispensers were kept at the proximity of egg bits.
3. The application was repeated after 8 to 10 days of first treatment imposition.

M2: As above but with septa impregranted with tricosane + pentacosane

Treated control (treatment 3):

M3: Treated control

1. Release of one Tricho card *(Trichogramma* parasitised *Corcyra* egg cards) which was cut into 16 bits and stapled on the cotton plants randomly.
2. After 8 to 10 days of first release one more Tricho card was cut into 16 bits and stapled on the cotton plants.

M4: Untreated control

A maximum recovery of 28.8% was recorded in M2 (Pentacosane+Tricosane-treated dispensers) which was significantly superior over M1 (Tricosane) and M3 (treated control) treatments. Untreated control recorded a minimum of 8.9 % recovery (Table 61). Minimum fruiting bodies damage of 12.9 % was recorded in Pentacosane+Tricosane-treated plot which was on par with Tricosane -treated plot and treated control plot but it was significantly superior to untreated control which recorded 17.6 % fruiting bodies damage. A maximum seed cotton yield of 1605 kg/ha was recorded in Pentacosane+Tricosane-treated plot which was on par with Module1. Untreated control recorded minimum seed cotton yield of 1395 kg/ha.

5.4 BIOLOGICAL SUPPRESSION OF TOBACCO PESTS

(i) Biological control of *Spodoptera exigua* in tobacco nurseries with biopesticides

CTRI

Nomuraea rileyi and *B. bassiana* both at 10^{13} spores/ha were as effective as neem seed kernel extract 2% in reducing damage to tobacco seedlings by *S. exigua* larvae. The EPN *Steinernema carpocapsae* @ 2 lakh IJ/ha was not as effective as the fungal pathogens.

DOR *Bt* @ 3 kg/ha was as effective as chlorpyriphos 0.05% spray in reducing the seedling damage to 8.8%. The seedling damage in control was 36.0%.

(ii) Validation of trap crop and border crop modules for the management of lepidopteran pests on tobacco

CTRI

Experiments were conducted in 5 locations in East Godavari district covering an area of 5 ha to evaluate trap crops castor DCS-9 for *S. litura* and *Tagetes* for *H. armigera*.

At 10 days interval 50 randomly-selected plants were observed for pest incidence/ damage and natural enemy incidence. Yield data was recorded.

The results of experiments from 2005-07 revealed that the percentage of plants damaged by *H. armigera* in tobacco sole crop was significantly higher than in tobacco associated with *Tagetes*. Except at 45 DAT, there was significant difference in damage between two seasons. Parasitisation by hymenoptera was significantly higher in tobacco

Table 62. Validation of *Tagetes* as trap crop (Pooled data 2005-2007)

Treatment	Plants damaged (%) (*H. armigera*)			Larval parasitisation (%) Hymenoptera *			Diptera **		
	30 DAT								
	A	B	AB	A	B	AB	A	B	AB
Tobacco sole crop	13.2	17.7	15.420.0	5.3	4.5	3.35.6	16.1	12.6	13.212.0
Tobacco + *Tagetes*	16.8	12.4	11.013.4	8.0	8.8	7.310.3	14.9	18.5	19.017.8
CD ($P = 0.05$)	2.1	1.2	NS	NS	3.1	NS	NS	1.7	NS
CV %	14.0	8.8		9.9	15.5		17.9	11.0	
	45 DAT								
Tobacco sole crop	13.4	31.9	18.59.2	10.1	14.5	7.321.6	0.0	1.7	0.03.3
Tobacco +*Tagetes*	11.0	15.6	8.412.9	18.0	13.6	12.914.2	3.7	2.0	0.04.2
CD ($P = 0.05$)	NS	12.1	2.9	2.2	NS	2.9	NS	NS	NS
CV %	21.8	16.3		15.2	9.8		24.3	14.5	
	60 DAT								
Tobacco sole crop	7.6	40.0	9.718.3	12.0	10.4	10.310.5	10.4	10.4	8.212.6
Tobacco + *Tagetes*	12.0	19.6	5.76.9	12.3	14.0	13.714.1	13.3	13.3	12.614.0
CD ($P = 0.05$)	2.9	2.0	2.8	NS	1.3	NS	1.7	1.3	1.9
CV %	15.3	10.6	15.2	31.6	10.6		14.2	11.0	

A – Seasons B – Treatments AB – Seasons x Treatments

**Apanteles, Campoletes chlorideae* ** *Carcelia illota, Peribaea orbata.*

with *Tagetes* than in tobacco grown alone. Between the seasons significant difference in parasitisation was not observed except at 45 DAT. Parasitisation by diptera was higher in tobacco grown along with *Tagetes* as border crop except at 45 DAT. Between the seasons the differences in parasitisation were significant only late in the season i.e. at 60 DAT (Table 62).

It can be concluded that *Tagetes* improved the natural enemy component (parasitisation) and reduced the damage caused by *H.armigera* in tobacco.

Per cent plants damaged by *S.litura* were significantly higher in tobacco sole crop than in tobacco grown alone. Between the seasons the occurrence of damage was significantly different. Damage was higher in the second year. Seasons had no impact on parasitisation by hymenoptera and diptera while tobacco grown with castor as trap crop had significantly higher parasitisation (Table 63).

Yields were 1.8% more where tobacco was grown with trap crops than in tobacco sole crop fetching an extra income of Rs. 1710/ha.

Constraints in adoption

1. Seeds of single whorl variety of *Tagetes* was difficult to o*B*tain as it has no commercial value and farmers need to develop their own stock of seed material.
2. Farmers preferred to grow *Tagetes* in between tobacco than around the field to avoid hindrance to cultural operations.
3. Castor was heavily infested by semilooper *Achaea janata* at some locations and farmers pulled out castor fearing semilooper might damage tobacco.
4. Farmers preferred to grow castor along the bunds but not around the fields to avoid hindrance to cultural operations. Farmers preferred dwarf castor variety as trap crop in tobacco.

Table 63. Validation of castor as trap crop (Pooled data 2005-2007)

Treatment	Plants damaged (%) (*S. litura*)			Larval parasitisation (%) Hymenoptera *			Diptera **		
	50 DAT								
	A	B	AB	A	B	AB	A	B	AB
Tobacco sole crop	13.1	18.5	15.821.1	15.9	12.2	12.212.3	8.3	7.8	7.38.4
Tobacco + Castor	18.0	12.7	10.515.0	15.6	19.2	19.618.9	9.8	10.3	9.311.3
CD (P=0.05)	2.6	1.1	NS	NS	2.6	NS	NS	0.8	NS
CV %	15.9	6.8		22.3	16.0		29.0	8.0	
60 DAT									
Tobacco sole crop	16.5	23.2	20.525.9	10.6	8.4	7.49.3	19.2	16.8	15.917.6
Tobacco + Castor	21.3	14.6	12.516.7	11.8	14.0	13.714.2	20.9	23.4	22.524.2
CD (P = 0.05)	2.6	1.8	NS	NS	1.8	NS	NS	2.3	NS
CV %	13.3	9.5		24.0	16.0		8.6	10.9	
70 DAT									
Tobacco sole crop	20.3	22.6	24.520.7	6.0	3.3	2.14.5	23.1	19.5	18.021.0
Tobacco + Castor	17.2	14.9	16.013.7	6.6	9.2	9.98.6	24.3	27.8	28.327.6
CD (P = 0.05)	2.6	1.4	NS	NS	2.8	NS	NS	1.1	1.6
CV %	13.6	7.0		7.5	13.3		17.6	4.5	

A – Seasons B – Treatments AB – Seasons x treatments

* *Chelonus formosana*, *Apanteles* sp., *Charops obtusa* ** *Peribaea orbata*

DAT: Days after transplanting

(iii) Field evaluation of adjuvants for *Ha*NPV against *H. armigera*

CTRI

An experiment was conducted on tobacco (cv. Hema) to evaluate certain adjuvants like boric acid, tannic acid, starch and crude sugar along with detergents for NPV of *H. armigera* applied @ 1.5 x 10^{12} POB/ha.

The data revealed that application of NPV @ 1.5 x 10^{12} POB/ha along with boric acid @0.025%, teepol 0.1% and detergent soap 0.1% was the most effective in reducing the larval population and leaf damage and increasing the yield of tobacco leaf (Table 64).

(iv) Evaluation of bio-agents and botanicals against root grubs

UAS (Shimoga)

Results of a field trial conduced at Sollepura farm near Hunsur revealed that application of 5 billion *Heterorhabditis indica* /ha protected tobacco seedlings from damage by white grubs resulting in enhanced survival of transplanted seedlings of tabacco (K-326) as well as yield of cured leaf. The EPN *H. indica* recorded 1797 kg/ha of cured leaf against 1520 kg/ha in control The fungus *M. anisopliae* applied through enriched FYM was ineffective. Neem cake applied at the rate of 60g/ plant recorded the highest yield of 1932 q/ha.

5.5 BIOLOGICAL SUPPRESSION OF PULSE CROP PESTS

(i) Evaluation of DOR *Bt* against the pod borers of pigeonpea

Experiments were conducted in farmer's fields in Tamil Nadu and Gujarat to assess the efficacy of *Bt* against the pod borers of pigeonpea. *Bt* was tested in doses of 2 and 1.5 kg per ha and compared with NSKE 5% and endosulfan 0.07%.

TNAU

The evaluation was conducted in Puthur village, Coimbatore district, on cv. Co4. The application commenced at 50% flowering stage and two rounds were given at 7 days interval.

Table 64. Efficacy of *Ha*NPV adjuvant on *Helicoverpa armigera*					
Treatment	Mean number of larvae/ plant		Leaves damaged (%)	Green leaf yield (kg/ha)	Cured leaf yield (kg/ha)
	3 days	7 days			
*Ha*NPV @ 1.5 x 10^{12} POB/ha + boric acid 0.025% + Teepol 0.1% + surf 0.1%	1.9^{c}	0.9^{c}	14.0^{c}	17894^{c}	2343^{bc}
HaNPV + tannic acid 0.025% + teepol 0.1% + surf 0.1%	2.0^{bc}	1.0^{bc}	14.5^{c}	17158^{c}	2229^{bc}
HaNPV + jaggery + teepol 0.1%	2.4^{b}	1.9^{b}	17.9^{b}	13624^{b}	1738^{b}
HaNPV + starch 0.1% + jaggery 0.1%	2.4^{bc}	1.1^{bc}	15.5^{bc}	14606^{b}	2229^{bc}
HaNPV + surf 0.1% + teepol 0.1%	2.1^{bc}	1.4^{bc}	17.7^{b}	14210^{b}	2122^{bc}
HaNPV alone	2.2^{bc}	1.6^{b}	14.8^{c}	13851^{b}	2097^{bc}
Control	3.6^{a}	3.0^{a}	20.5^{a}	9429^{a}	1322^{a}
Means followed by the same letter in a column are not significantly different (P=0.05)					

The data revealed that *Bt* was ineffective against the pod borers of pigeonpea in reducing the pod damage though there was a reduction in the population of the different species of pod borers. NSKE 5% was as effective as endosulfan in controlling the pest and increasing the grain yield (Table 65).

ANGRAU

The field evaluation of DOR *Bt* was done during *Kharif* 2006-07 at ARS, Tandur. The data showed that DOR *Bt* did not give significant control of the pest. The yield differences between the different treatments as well as control were not statistically significant.

AAU(A)

(a) Laboratory studies

In laboratory tests DOR *Bt* @ 2g/l produced 60.1% mortality of *H. armigera* larvae and 65.1% mortality of *Lampides* sp. as well as *Exelastis atomosa*.

(b) Field experiment on BDN-2 pigeonpea

Results of two season trials (2005-06 and 2006-07) indicated that *Bt* was able to reduce the population of different species of borers as well as pod damage significantly and increase the yield of seeds. However, the net return was found to be highest in endosulfan followed by NSKE 5% (Table 66).

(ii) Evaluation of BIPM package on soybean

CTRI

The BIPM package consisting of release of *Telenomus remus* against *S. litura* @ 1 lakh parasitoids/ha as soon as the egg masses of *S. litura* are observed, one spray of *Sl* NPV @ 1.5 x 10^{12} PIB/ha along with 0.5% crude sugar as adjuvant and one spray of *Bt kurstaki* @ 2 kg/ha as soon as early instar larvae are seen was compared with farmer's practice of sprays of chemical insecticides.

There was a significant reduction of larval population of *S. litura* in BIPM after release of *T. remus* as well as after one spray of SI NPV over FP wherein one spray of chlorpyriphos was applied. A application of *Btk* was ineffective against the leaf webber. Yield of soybean seeds in BIPM was higher than in chemical control plot and the benefit was Rs. 4120/ha.

NRCS

The trial was conducted during *kharif* on the farm of Shri Shyamalal Patidar at village Jamli,

Table 65. Field efficacy of DOR *Bt* against pigeon pea borer complex at Puthur village, Coimbatore

Treatment	Post treatment (No. larvae/plant)			Pod damage (%)	Grain yield (kg/ha)
	Helicoverpa armigera	*Maruca testulalis*	*Exelastis atomosa*		
DOR *Bt* 2kg/ha	5.6^{b}	1.2^{c}	0.2^{a}	18.8^{b}	431.2^{b}
DOR *Bt* 1kg/ha	6.3^{b}	0.5^{b}	0.2^{a}	21.1^{b}	410.0^{b}
NSKE 5%	2.6^{a}	1.1^{c}	1.0^{b}	11.5^{a}	525.0^{a}
Endosulfan 0.07%	1.8^{a}	0.2^{a}	0.1^{a}	13.1^{a}	531.1^{a}
Control	14.2^{c}	4.5^{d}	1.1^{b}	19.2^{b}	412.1^{b}

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 66. Efficacy of *Bt* against the pod borers of pigeonpea at Anand

Treatments	Larvae/10 plants			% Pod damage	Seed Yield	Net return
	Lampides sp.	*Exelastis atomosa*	*H. armigera*	(kg/ha)	Rs/ha	(over control)
DOR *Bt* @ 2kg/ha	1.4^{a}	2.5^{ab}	1.5^{b}	14.41^{ab}	1229^{ab}	1,122
DOR *Bt* @ 1kg/ha	1.2^{a}	3.0^{b}	1.7^{c}	16.19^{b}	1121^{bc}	1,746
NSKE @ 5%	1.4^{a}	3.4^{b}	2.0^{d}	19.30^{b}	1207^{ab}	7,008
Endosulfan @ 0.07%	0.8^{a}	1.80^{a}	1.1^{a}	12.21^{a}	1427^{a}	11,928
Control	2.7^{b}	5.5^{c}	3.8^{d}	22.54^{c}	903^{c}	-

Means followed by the same letter in a column are not significantly different (P=0.05)

Tehsil Mhow, Indore on Soybean variety *Samrat.*

Kharif 2006 started with good conditions for germination and crop establishment. The incidence of seedling insect-pests viz. blue beetle (*Cneorane* spp.), linseed caterpillar (*S. exigua*) and stem fly (*Melanagromyza sojae*) was negligible. As soon as the first generation of *S. litura* and also the egg masses were noticed (3rd week of August), 1st release of *T. remus* was made. In FP plots, Triazophos 40 EC was sprayed @ 0.8 l/ha. To supplement the effect of parasitoid, *Sl* NPV was sprayed in BIPM, which had marked effect on larval population (4.21arvae/m after 5 days of spray). In FP plots it increased to 13.71arvae/m in same duration.

By the end of 2nd week of September, second generation egg masses of *S. litura* were noticed along with incidence of green semiloopers' complex comprising of *Chrysodeixis acuta*, *Plusia orichalcea* and *Gesonia gemma* (13.2 larvae/m in BIPM & 13.9 in FP). Second release of *T. remus* was followed by spray of *Bt* (Dipel) @ 2 ml on the next day in BIPM plots for the control of green semiloopers. After 7 days of release of *T. remus*, the populations of *S. litura* in BIPM plots was only to 4.61arvae/m as against 13.91arvae/m in FP plots. On the other hand, after 7 days of spray of *Bt*, the population of green semiloopers in BIPM plots was also significantly reduced to 2.3 larvae/m as against 14.11arvae/m in FP plots (Table 67).

There was a significant difference between the yield realized from BIPM plots and FP plots. The BIPM plots yielded 23.45 q/ha, whereas only 18.85 q/ha could be harvested from FP plots. With the use of BIPM package, additional yield of 4.6q/ha i.e. 24.4% could be realized.

Table 67. Comparison of BIPM package and farmers' practice for incidence of defoliators in soybean and grain yield

Insect incidence	BIPM	FP
S. litura (larvae/m) 7 days after 1st release of *T. remus*	8.9	6.8
S. litura (larvae/m) 5 days after Sl NPV spray	4.2	13.7*
S. litura (larvae/m) 7 days after 2nd release of *T. remus*	4.6	17.4 *
Green semiloopers (larvae/m) 1 day before *Bt* spray	13.2	13.9
Green semiloopers (larvae/m) 7 days after spray	2.3	14.1*
Grain yield (kg/ha)	2345	1885*

* Differences between BIPM and FP significant by 't' test

5.6 BIOLOGICAL SUPPRESSION OF RICE PESTS

(i) Evaluation of DOR *Bt* against leaf folder

The efficacy of the *Bt* formulation developed by Directoarate of Oilseeds Research (DOR *Bt*) was evaluated in multilocation trials for efficacy against the leaf folder and stem borer of rice.

KAU

Results of the experiment at Karimangalam on Jyothi rice indicted that two sprays of DOR *Bt* @ 1.5 kg/ha reduced the leaf folder damage but not stem borer. At a higher dose of 2.0 kg/ha, DOR *Bt* recorded the highest grain yield (Table 68).

AAU(J)

The experiment at Jorhat also showed that DOR *Bt* was effective in controlling the pests or rice including the stem borer. The *Bt* treatments recorded higher yield of grain than the chemical insecticide (Table 69).

PAU

Evaluation of DOR *Bt* against leaf folder and stem borer of rice was conducted at farmer's field at Samrala (Distt. Ludhiana). The data revealed that DOR *Bt* @ 2 kg/ha was significantly more effective than monocrotophos in reducing the damage by lef folder and stem borer. Highest grain yield of 5890 kg/ha was recoded in DOR *Bt* @ 2 kg/ha which however was on par with monocrotophos (Table 70).

Table 68. Efficacy of DOR-*Bt* against rice leaf folder and stem borer

Treatment	Leaf folder larvae/	Leaf folder damage (%) hill	Dead hearts (%)	Grain yield (kg/ha)
DOR *Bt* @2 kg/ha	0.1[a]	0.2[a]	6.1[b]	4788[a]
DOR *Bt* @ 1.5 kg/ha	0.1[a]	0.4[a]	5.4[b]	4250[ab]
Ekalux 0.05%	0.1[a]	0.2[a]	1.4[a]	4578[ab]
Control	0.5[b]	2.5[c]	6.7[b]	3863[b]

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 69. Efficacy of DOR-*Bt* against rice leaf folder and stem borer

Treatment	Leaf folder	Caseworms/ 10 plants damage (%)	Dead hearts (%)	Grain yield (kg/ha)
DOR *Bt* @2 kg/ha	1.5[a]	2.0[a]	2.2[a]	3087.5[a]
DOR *Bt* @ 1.5 kg/ha	1.4[a]	3.0[b]	2.8[b]	2992.3[a]
Chlorpyriphos	1.7[a]	3.0[b]	2.8[b]	2847.8[b]
Control	6.0[b]	7.0[c]	9.0[c]	2381.5[c]

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 70. Efficacy of DOR-*Bt* against rice leaf folder and stem borer of rice (cv. PR 116)

Treatment	Leaves folded (%)		Dead hearts (%)	White ears (%)	Grain yield (q/ha)
	45 DAT	60 DAT	60 DAT		
DOR-*Bt* @2.0 kg/ha	0.4[a]	0.3[a]	0.8[a]	1.1[a]	58.9[a]
DOR-*Bt* @ 1.5 kg/ha	0.5[ab]	0.5[b]	1.5[c]	1.9[b]	57.5[b]
DOR-*Bt* @ 1.0 kg/ha	0.6[b]	0.5[b]	2.6[d]	2.1[c]	56.1[c]
Monocrotophos 36 SL	0.5[a]	0.4[ab]	1.3[b]	1.3[a]	58.8[a]
Control	2.2[c]	1.8[c]	3.8[e]	2.3[c]	55.4[d]

Means followed by the same letter in a column are not significantly different (P=0.05)

(ii) Validation of biointensive pest management practices in organic rice production

PAU

The experiment on validation of BIPM in organic rice production was carried out at PAU, Ludhiana on *Basmati* rice and coarse rice. In the organic farming, green manuring was done with *Dhaincha* (*Sesbania aculeata*); *T. chilonis* and *T. japonicum* were released 3 times each @1,00,000/ ha at weekly interval starting 30DAT; In the recommended practices nutritional requirement was met with inorganic recommended fertilizers and in the integrated practices, half of the nutritional requirement was met with inorganic fertilizers and other half with organic fertilizers, 3 releases of *T. chilonis* and *T. japonicum* each @1,00,000/ha were done at weekly interval starting 30DAT.

On rice (Table 71), the incidence of stem borer at 60 DAT was lower in organic practices (0.3%) as compared to integrated practices (0.4%) and recommended practices (0.5%). The per cent white ears in the integrated practices and organic practices were lower (0.4%) than recommended practices (0.6%). The yield was highest in integrated practices (71.0q/ha) as compared to organic practices (62.8q/ha) and recommended practices (58.0q/ha).

Table 71. Validation of bio-intensive pest management practices in organic rice in Punjab during 2006

Treatment	Dead hearts (%)	White ears (%)	Grain yield (kg/ha)
Organic practices	0.3	0.4	6280
Recommended practices	0.5	0.6	5800
Integrated practices	0.4	0.4	7100

Table 72. Validation of bio-intensive pest management practices in organic *Basmati* rice in Punjab during 2006

Treatment	Leaves folded (%)	Dead hearts (%)	White ears (%)	Grain yield (kg/ha)
Organic practices	0.2	0.7	0.8	2420
Recommended practices	0.6	1.2	1.4	2790
Integrated practices	0.3	1.1	1.2	3220

On *Basmati* rice (Table 72), the incidence of the leaf folder at 60 DAT was slightly lower in organic practices as compared to integrated practices and recommended practices. Whereas the incidence of stem borer at 60 DAT was lower in integrated practices than organic practices and recommended practices. The per cent white ears were lowest in organic practices followed by integrated practices and recommended practices. The yield in the integrated practices was higher (32.2q/ha) than in recommended practices and organic practices.

It can be concluded that releases of *T. chilonis* and *T. japonicum* 3 times @ 1,00,000 per ha 3 times at weekly interval reduced the incidence of leaf folder and stem borer in organic and *Basmati* rice.

Organic practices	Recommended practices	Integrated practices
Green manuring with daincha; 3 releases inorganic *T. chilonis* and *T. japonicum* each 1 lakh/ha 30 DAT, 2nd, 6 weeks after transplanting	Recommended dose of fertilizer, 1st after 3weeks and second after 6weeks transplanting	Fertilizers: ½ the recommended dose of inorganic fertilizer in 2 splits; 1st 3 weeks after transplanting + ½ of organic manure; 3 releases of *T. chilonis* and *T. japonicum* each 1 lakh/ha 30 DAT

KAU

During *kharif* and *rabi* 2006-07, biointensive pest management package was demonstrated over an area of 0.5 ha of rice variety Jyothi. The package consisted of farm yard manure @ 5 t/h, seed treatment with *Pseudomonas* @ 8g / kg, bird perches @ 10 nos / h and four releases of *T. japonicum* against stem borer and leaf folder. The results showed that coccinellid and spider counts were significantly higher in organic farming in both seasons. There were no significant differences in the damage caused by the stem borer and leaf folder during the *kharif* season but organic package recorded significantly lower damage by these pests during *rabi*. There was no significant variation in grain yield in *rabi* season, but in *kharif* season grain yield was significantly higher in organic farming plot with higher net return (Table 73).

AAU(J)

Validation of biointensive pest management practices in organic rice production against sucking pest, leaf folder and rice stem borer was conducted in a farmer's field during *kharif* 2005 and 2006. In the experiment there were three treatments

T_1: **Organic package**

Use of moderately resistant variety (cv. Ranjit)

Use of *Pseudomonas* (8 g/kg of seed) as seed treatment

Application of FYM (5 t/ha)

Application of *B.bassiana* (10^{13} spores/ha)

Use of bird perches (10/ha)

Release of *T. japonicum* (1 lakh/ha/week)

Spray of *P. fluorescens* (as per university recommendation)

T_2: **Conventional package** (chemical control)

T_3: **Farmers practice**

The pooled data for *kharif* 2005 and 2006 revealed that the organic package was superior in reducing the damage caused by green leaf hopper, leaf folder and stem borer as compared to conventional package and farmers' practice. Organic package gave the highest grain yield (3368.1 kg/ha) as against 2527.9 kg/ha in the farmers field (Table 74). However, no significant difference of

Table 73. Impact of organic farming on the pests of rice (cv. Jyothi) in Thrissur

Parameter	*Kharif*			*Rabi*
	Organic	Conventional	Organic	Conventional
Dead hearts (%)	4.2	5.3	3.5	6.5
Leaf folder incidence(%)	1.7	1.4	0.2	1.1
Coccinellids/ hill	0.3	0.05	0.5	0.1
Spiders/ hill	0.6	0.1	0.4	0.04
Grain yield (kg/ha)	3954.7*	3722.0	3640.0	3825.0

* Values significantly different from conventional package

Table 74. Validation of bio-intensive pest management package in rice (cv. Ranjit) in Assam			
Parameter	Package		
	Organic	Conventional	Farmer's
GLH/ hill	7.2[a]	6.6[a]	14.8[b]
Leaf folder damage (%)	2.6[a]	4.6[b]	6.9[c]
Dead hearts (%)	3.9[a]	6.3[b]	10.6[c]
Yield of grain (kg/ha)	3368.1[a]	2926.2[b]	2527.9[c]
Net return (Rs. /ha.)	20501.0	16689.0	-

Means followed by the same letter in a column are not significantly different (P=0.05)

yield was found between conventional package and organic package. The cost benefit analysis showed that organic package gave the highest net profit (1: 8.30) in comparison to the conventional package.

NCIPM

On farm trial to validate bio-intensive pest management practices in organic rice (HSB-16) locally known as Taraori Rice was carried out at Kaithal in farmers participatory mode. The experiment was laid out in 0.5 ha area in certified organic as well as in conventional fields. This rice is susceptible to yellow stem borer, leaf folder and foliar diseases except partial resistance to neck blast. Field preparation was carried out as per organic norms and the field was augmented with *Trichoderma*-treated farm yard manure @ 6T/ha. Seed soaking with 1% *P. fluorescens* was given to manage seed-borne diseases. As a preventive measure, seedling root dip treatment was also carried out with 2% *P. fluorescens* before transplantation. Leaf folder made its appearance from August end, hence *B. bassiana* was sprayed to confine the level of damage. The crop was sprayed with *P. fluorescens* @ 2kg/ha as a preventive measure to contain foliar diseases.

In case on conventional trial the field was prepared as per recommended practices of Haryana state. The crop was sprayed with chemical pesticides such as Cartap 4G @ 1 kg a.i./ha and chlorpyriphos 20 EC @ 2 ml/lit to contain the insect menace. Similarly, fungicides such as carbendazim and hexaconazole were sprayed to contain brown spot and bacterial leaf blight. Observations were carried out in 36, 37 and 38[th] standard meteorological weeks for assessing the effectiveness *B. bassiana* with the help of percentage incidence of leaf folder. The incidence of yellow stem borer was quite less during this period hence the same has not been analyzed. The data was transformed using angular transformation. Repeated measurement ANOVA analysis was carried out using "Proc Mixed" of SAS software. The analysis of data indicated that the differences in the incidence of leaf folder in the crop managed through biointensive practices was significantly lesser in biointensive package than in farmers package.

Soil analysis indicated that the field under biointensive trial contains 0.37% of organic carbon in comparison to 0.35% in farmers' practices trial. The final yield of bio-intensive trial (1318 kg/ha) was higher than farmers practice (1191 kg/ha) (Table 75). It is worthy to note that bio-intensive trial was carried out in certified organic fields which is in fifth year and has completed all the formalities of conversion as per international standard and being certified by Indian office of M/S Skal International.

Table 75. Validation of bio-intensive pest management package (BIPM) in organic rice in Kaithal				
Treatment	Leaf folder (%) at standard meteorological week			Grain yield (kg/ha)
	36	37	38	
BIPM	8.9	10.2	8.3	1318.0
Farmer's practice	32.4	19.3	18.2	1191.0

(iii) Large-scale demonstration of bio-intensive IPM of *Basmati* rice

PAU

Biocontrol-based IPM was demonstrated in a 10ha plot at Karni Khera (Distt. Ferozepur) on variety *Basmati* - 386. In IPM plots, one application of cartap hydrochloride (Padan 4G) @ 25kg/ha was made; 7 releases of *T. chilonis* and *T. japonicum* were made each @ 1,00,000/ha/at weekly interval, starting 30 DAT. In chemical control, three applications of cartap hydrochloride (Padan 4G) were given @ 25kg/ha, 30, 50 and 70 DAT. These two packages wre compared with untreated control.

The incidence of leaf folder and stem borer in control was significantly higher than IPM and chemical control (Table 76). The lowest incidence of leaf folder (0.5% and 0.4%) was recorded in IPM (45DAT and 60 DAT), which was significantly lower than chemical control (2.1%, 45DAT and 1.1%, 60 DAT). The dead hearts in chemical control (0.5% and 0.6%) was on a par with IPM (0.7% and 1.0%) at 45 DAT and 60 DAT. The incidence of white ears in IPM (2.2%) and chemical control (1.8%) was significantly lower than control (4.0%). The yield in IPM and chemical control was significantly higher than in control.

(iv) Validation of BIPM practices against pest complex of organic rice

KAU

This experiment was conducted in an area of 4 ha in Kanimangalam on rice (cv. Jyothi) during *rabi* 2006-07 to compare organic pest management with chemical insecticides. In biocontrol packages, *P. fluorescens* was used for seed treatment. Dewatering the field and neem oil spray was given for case worm management. *T. japonicum* @ 1 lakh/h was released four times fortnightly intervals against stem borers and leaf folders. It was found that the incidence of plant hoppers, leaf folders and stem borer was significantly lesser in organic rice than in conventional pest management package. The organic rice plots recorded significantly higher number of predators. The difference in grain yield however was not significant (Table 77).

5.7 BIOLOGICAL SUPPRESSION OF OILSEED CROP PESTS

(i) Identification of natural enemies of mustard sawfly for use in biocontrol

AAU(J)

Field population of mustard sawfly was collected at weekly intervals from Instructional-

Table 76. Evaluation of large-scale biocontrol-based IPM in Basmati rice at Karni Khera (Distt. Ferozepur) in Punjab during 2006

Treatment	Leaves folded (%)	Dead hearts (%)	White ears (%)	Grain hield (kg/ha)
IPM	0.4[a]	1.0[a]	2.2[b]	3210[a]
Cartap hydrochloride @ 25 kg/ha (padan 4g)	1.1[b]	0.6[a]	1.8[a]	3440[a]
Control	2.3[c]	2.2[b]	4.0[c]	2690[b]

Means followed by the same letter in a column are not significantly different (*P*=0.05)

Table 77. Validation of BIPM in organic rice in Kanimangalam

Treatment	Dead hearts (%)	Plant hoppers/ hill	Leaf folder larvae/ hill	Predators / hill Coccinellids	Spiders	Grain yield (kg/ha)
Organic	0.8[a]	0.5[a]	0.2[a]	0.6[a]	0.3[a]	7928
Conventional	2.6[b]	1.7[b]	1.0[b]	0.1[b]	0.04[b]	7989

Means followed by the same letter in a column are not significantly different (*P*=0.05)

cum-Research Farm, Assam Agricultural University, Jorhat and also from Alengmora, Jorhat and reared in the laboratory in wooden cages covered with nylon net for the emergence of natural enemies. However, the field-collected mustard sawflies were completely free from the attack of natural enemies.

MPKV

To identify the natural enemies of mustard sawfly, eggs and larvae were collected at three days interval from mustard and radish fields and were reared in laboratory and were regularly observed for parasitoid occurrence. But during this period no parasitoids were observed.

(ii) Laboratory screening of mustard sawfly larvae for susceptibility to DOR-5 (*Bt*) and other commercial *Bt* products

AAU(J)

Probit analysis of dose-mortality response revealed that there were only minor differences in the toxicity of the different *Bt* products. DOR *Bt* recorded the lowest LC_{50} at 96 h post treatment (Table 78). By 144 h post treatment however, all the *Bt* products recorded 100% mortality.

Table 78. Probit analysis of dosage mortality response of mustard sawfly larvae to different formulations of *Bt* 96 h post treatment

Bt source (n-2)	Chi^2 'b'	Slope	LC_{50} (g/l)	Fiducial limits	
				Upper	Lower
DOR *Bt*	10.06	1.1	0.84	1.20	0.22
Biolep	13.17	3.3	0.93	1.06	0.70
Dipel	19.47	1.89	0.91	1.13	0.66
Biobit	12.88	1.86	1.30	1.90	0.99

5.8. BIOLOGICAL SUPPRESSION OF MAIZE PESTS

(i) Control of cutworm *Agrotis ipsilon* on maize with EPN

SKUAS&T (Jammu) in collaboration with PDBC

Results of the field trial on the efficacy of EPN against the cut worm *A. ipsilon* on maize revealed that application of *H. indica* @ 2 billion/ha resulted in lowest population and damage by *A. ipsilon* and highest yield (Table 79).

5.9. BIOLOGICAL SUPPRESSION OF COCONUT PESTS

(i) Evaluation of *Trichogramma embryophagum*, *Goniozus nephantidis* & *Cardiastethus exiguus* against *Opisina arenosella*

KAU

Data from a field experiment conducted at Vatanapilly beach area in Thrissur district showed that release of the different parasitoids and predator effectively reduced the population of the black headed caterpillar. Sequential release of *C. exiguus* and *G. nephantidis* was as effective as the release of the individual agent (Table 80).

Release of *T. embryophagum* was not as effective as the other natural enemies.

(ii) Biological suppression of *Oryctes rhinoceros* with *Metarhizium anisopliae* in homestead garden in Kerala

KAU

The experiment was carried out in three locations in Thrissur district, Vellanikkara, Mannuthy and Nettissery. *Metarhizium anisopliae* mass cultured in glass bottles containing coconut water.

Table 79. Evaluation of EPN against cutworm *Agrotis ipsilon* on maize

Treatment	Dose	Larval population/10 plants	Damaged plants (%)	Yield (kg/ha)
S. carpocapsae	1 b/ha	2.75	8.2	1685
S. carpocapsae	2 b/ha	2.25	7.3	1755
H. indica	1 b/ha	2.00	6.2	1840
H. indica	2 b/ha	1.25	5.0	2000
Control	-	3.75	10.4	1560

Table 80. Efficacy of natural enemies against *Opisina arenosella*	
Treatment	Larvae/10 leaflets
T. embryophagum adults @ 1000/ palm	1.3
C. exiguus nymphs @ 50/palm	0.6
G. nephantidis adults @ 10/palm	0.6
Sequential release of *T. embryophagum* & *G. nephantidis*	0.3
Sequential release of *C. exiguus* & *G. nephantidis*	0.3
Untreated control	3.3

Twenty-five days after inoculation, the fungal mass was applied in manure pits @ 10 bottles / sq.m area. The fungus could kill all the larvae in the pits within three months in all three locations. Subsequently the incidence of the pest was reduced from 100% at the beginning of the experiment to 6.6% after three months.

(iii) Field evaluation of new formulations of *Hirsutella thompsonii* against coconut mite

PDBC

Results of a field trial laid out at Huskuru (Bangalore Rural district) on the efficacy for evaluating of *H. thompsoniii* (mycelial formulation) in combination with three selected adjuvants against the coconut mite, showed that three sprays of *H. thompsoniii* in combination with either glycerol, yeast extract powder or malt extract broth (MEB) significantly reduced the population of the coconut mite on the nut surface. The fungus was able to cause disease in the mite on all the sprayed trees as evidenced during the post-treatment sampling and reduced the population by about 90 %. Pre-harvest scoring of damage on the nuts indicated that *H. thompsonii* + glycerol 0.5% as an adjuvant was the most effective in reducing the injury caused by the mite (Table 81).

KAU

Results of the trial at Kerala also indicated that *H. thompsonii* along with adjuvants could reduce the population of the mites as effectively as the acaricide, dicofol. But pre-harvest scoring of nuts for damage did not show any significant effect of *H. thompsonii*.

(iv) Biological control of *O. arenosella* using *Bracon* spp.

CPCRI

Bracon species were collected from 7 locations namely, Kasaragod, Kollam (Cantt.), Kollam (Asramam), Trivandrum and Kottayam of Kerala, Aliyarnagar of Tamil Nadu and Pitappally of Orissa. These collections were maintained individually in the laboratory. The comparative efficiency of the collections was assessed with regard to longevity, fecundity, female progeny production and number of host larvae parasitised. The data indicated significant difference in these characters between the collections. Kasaragod and Pitappally (Orissa) collections were superior to others with regard to longevity, number of larvae parasitised and fecundity. Female progeny production was more in Trivandrum and Orissa cultures.

Table 81. Field evaluation of new formulations of *Hirsutella thompsonii* against *Aceria guerreronis*

Treatment	Live mites (no./mm^2)		Damage grade
	Pre-treatment	Post-treatment	
H. thompsonii (1%) + glycerol (0.5%)	5.22	0.84^a	1.96^a
H. thompsonii (1%) + yeast extract (0.5%)	7.19	1.61^a	2.13^a
H. thompsonii (1%)+ malt extract (0.5%)	8.27	0.31^a	2.16^a
Triazophos (Trifos 40) (0.2%)	6.43	0.71^a	1.98^a
Control	8.81	11.18^b	4.01^b

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 82. Efficacy of biocontrol components against *Oryctes rhinoceros*

Treatment	Leaf damage (%)		Reduction in leaf damage (%)
	Pre-treatment	Post-treatment	
OBV+GMF+ pheromone trap	27.3	14.5	45.9
GMF+OBV	25.2	17.9	31.7
GMF trap	26.6	25.9	3.7
OBV release	18.0	10.5	44.4
Pheromone trap	31.5	30.8	15.5
Control	31.5	30.8	3.2

(v) Management of *Oryctes rhinoceros* through integration of green muscardine fungus (GMF), *Oryctes* baculovirus (OBV) and attractant-baited pheromone traps

CPCRI

The experiment was conducted at Krishnapuram with six treatments. Each plot consisted of an area of 1 acre in different blocks of CPCRI farm. Observations were recorded from 15 palms under each treatment. The percentage of leaf damage was recorded prior to initiation of treatment and also at 6 months interval (Table 82). There was 3.7 to 45% reduction in leaf damage in various treatments. Maximum percentage reduction in leaf damage (45.9%) was obtained in the plot where all the three components were imposed, viz. OBV+GMF+ Pheromone trap followed by OBV release plot (44.4%). There was an average collection of 216 beetles/trap/year in the pheromone trap.

5.10. BIOLOGICAL SUPPRESSION OF PESTS IN TROPICAL FRUITS

(i) Population dynamics of *Coccus viridis* and its natural enemies on sapota

IIHR

The population of green scales ranged from 11.8/leaf in July to 1.1/leaf in December 06 (Table 83). During the study period, the aphelinid parasitoid *Coccophagus* sp. and the two coccinellid predators *Chilocorus nigrita* and *Cryptolaemus montrouzieri* were observed. The parasitism by *Coccophagus* sp. ranged from 60.2% in April 2006 to 93.4% in October 2006. The predator *Chilocorus nigrita* was observed in negligible numbers in August to December 06 (Fig.15). The population of the scale was found to be very low mainly due to the activity of *Coccophagus* sp.

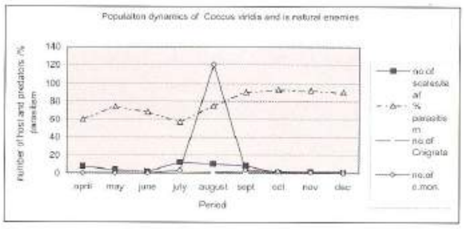

Fig. 15. Population of the soft green scale parasitised by *Coccophagus* sp. and other natural enemies

(ii) Effect of off-season release of *C. montrouzieri* on mealybugs on custard apple

IIHR

Release of *C. montrouzieri* @ 30 larvae/ plant in off-season before fruit setting (about three months prior to harvesting of fruits) resulted in the reduction of 37.0% infestation on plant and 18.9% on fruits during fruiting season of October 2006.

(iii) Toxicity of newer pesticides to *C. montrouzieri*

IIHR

A total of eight new molecules were tested for their relative toxicity to the adults of *C. montrouzieri*. Both the initial toxicity on the day of application and residual toxicity at different days after application were studied. Among them, profenophos + cypermethrin and bifenthrin both at

1ml/l proved to be the most toxic to the adult beetles causing 80 –100% mortality on the day of application. Imidacloprid 0.5ml/l, abamectin 0.5ml/lit, fluvalinate 0.5ml/l, profenophos 1ml/l, ethofenprox 1ml/l, flufenoxuron 1ml/l did not cause any mortality of *C. montrouzieri* on the day of application. Residual toxicity studies indicated that profenophos + cypermethrin proved to be harmless on 7th day of application while bifenthrin proved to be safe only on 14th day of application to the adult beetles.

(iv) Evaluation of *Bt* formulations against the leaf miner on acid lime and pomello

IIHR

The effect of commercial formulations of *Bacillus thurinigiensis* var. *kurstaki* (*Btk*), viz. Dipel, and Halt were evaluated against *Phyllocnistic citrella* in Pomello. Totally, there were six treatments including unsprayed control: Dipel @ 0.5 and 1 ml/L, Halt @1ml/l followed by Neem soap @10g/l and Deltamethrin @ 2ml/l were evaluated. A total of six sprays were given at weekly interval. Insecticide was given at fortnightly interval.

A mean larval population of 0.9, 1.6 and 2.7 was recorded in *Bt* formulations (Dipel @1 and 0.5 ml/l, Halt @1ml/l) that was found to be at par to check (0.7 larvae/plant) and significantly less than control (5.5larvae/plant). Among the various *Bt* formulations, Dipel @ 1 ml was observed to record minimum leaf miner incidence

(v) Demonstration trial on the use of *C. montrouzieri* for controlling the pink mealybug *Maconellicoccus hirsutus* on grapes

NRCG in collaboration with PDBC & IIHR

Severe infestation of the pink mealybug *Maconellicoccus hirsutus* was observed in the grape orchard (cv. Thompson seedless) of 5 hectares at Tuljapur near Solapur in Maharashtra in March 2006. A mean of 70.5% of the bunches were found infested with the pink mealybug in spite of the application of 17 sprays of insecticides like dichlorvos, carbaryl, imidacloprid, methomyl, clothianidin, thiamethoxam, etc. The crop was pruned on 13 October 2006. Thrips and flea beetles were managed with the application of dochlorvos, imdacloprid and spinosad up to 60 days after pruning. Release of Australian ladybird beetle *C. montrouzieri* was initiated on 14 December 2006 and continued up to 10 February 2007. A total of 25000 larvae of *C. montrouzieri* were released @5000/ha during the above period.

Observations revealed that the predators effectively controlled the population of the mealy bugs and reduced the incidence to just 0.95% by March 2007.

5.11. BIOLOGICAL SUPPRESSION OF PESTS OF TEMPERATE FRUITS

(i) Development of bio-intensive IPM for San Jose Scale, *Quadraspidiotus perniciosus* in apple ecosystem

SKUAS&T

Analysis of data on parasitism of San Jose scale from samples of infested twigs, collected from different orchards, viz. IPM-managed orchard, Farmers' orchard and unmanaged orchard from March to September revealed varying pattern of parasitism. Average number of scales/ 2 sq.cm in IPM orchards was always much lower than in non-IPM orchards during all the periods of observations. Per cent parasitism however was found comparatively higher in IPM than in non-IPM plots.

The results indicated that usefulness of release of the parasitoid at more than 100/ tree for the management of the San Jose scale.

(ii) Field evaluation of *Trichogramma embryophagum* against the codling moth, *Cydia pomonella* on apple

SKUAS&T

Five Tricho cards/ tree, each containing 2000 eggs parasitised by *T. embryophagum* were used alone and in combination with mating disrupting pheromone (Disrupt CM Xtra) and chlorpyriphos (0.05%) during 3rd week of June 2006 both at Leh and Kargil, and data collected on infestation on fallen fruits as well as fruits on tree. Data revealed that *T. embryophagum* in combination with chlorpyriphos reduced the infestation of both fallen fruits and fruits on trees by 53.6 and 58.8%

followed by mating disrupting pheromone + *T. embryophagum* (49.0 and 53.0%). *T. embryophagum* alone could reduce the infestation only by 3 to 6% at both Leh and Kargil.

Future investigation will focus on timing, frequency, dosage and mode of release of *T. embryophagum* in order to evaluate its effectiveness against the codling moth.

(iii) Evaluation of fungal pathogens against the European red mite, *Panonychus ulmi*

SKUAS&T

Various fungal pathogens, viz. *V. lecanii, H. thompsonii, B. bassiana* and *M. anisopliae* each at concentration of 1x 10^9 spores/ml were evaluated for their efficacy against the European red mite, *Panonychus ulmi* under laboratory conditions in the division of Entomology, SKUAST-K. Leaf discs were made from fresh apple leaves and evaluation was carried out by leaf disc application (dipping) method.

The mortality data indicated that *V. lecanii* and *H. thompsonii* were the most effective recording a mortality of 43.3% on day nine and 53.3% on day 15 (Table 83).

Table 83. Relative susceptibility of *Panonychus ulmi* to fungal pathogens

Treatment	Mortality (%) (days after application)		
	3	9	15
V. lecanii	33.3	43.3^a	53.3^a
H. thompsonii	20.0	43.3^a	53.3^a
B. bassiana	13.3	23.3^b	36.6^b
M. anisopliae	33.3	30.0^b	36.6^b
Control	10.0	16.6^b	23.3^b

Means followed by the same letter in a column are not significantly different (P=0.05)

(iv) Mass production of predatory mites

Dr.YSPUH&F

The culture of the predatory mite, *Amblyseius longispinosus* was maintained in winters on *Tetranychus telarius* grown on excised mite-infested rose leaves kept on wet sponge in Petri plates. It was found to be a good predator of the two spotted spider mite. It preferred nymphs and adults to eggs. At a minimum and maximum temperature range of 0.5-5.9°C and 18.4-22.7°C and relative humidity range of 20-91%, adults survived for 19.4 ± 12.9 (4 - 37) days. The predatory mite completed its development from egg to adult stage in 8.8 days. A single female laid 11.2 ± 4.9 (maximum 17) eggs in her life-time in winter with a survival of 4-37 (19.4 ± 12.9) days but hatchability was 100%. Thus it was possible to maintain the culture of these predatory mites in winter.

Recently, a predatory mite *Amblyseius (Euseius) delhiensis* has been collected and found feeding on *T. telarius* and the greenhouse whitefly nymphs, *Trialeurodes vaporariorum*.

(v) Evaluation of some microbial agents against apple root borer, *Dorysthenes hugelii*

Dr.YSPUH&F

First instar larvae of the apple root borer were found sensitive to RPN *S. feltiae* applied at 2X10^5 IJs/m^2. All larvae died in 10 days. Nematodes were found in the body of dead larvae. Recently, some mycosed grubs have been collected from the field and the fungus appears to be *Metarhizium anisopliae*.

(vi) Control of edaphic populations of the apple woolly aphid using EPN

Dr.YSPUH&F in collaboration with PDBC

The EPNs, *Heterorhabditis bacteriophora* (2.83 lakh IJs/tree) and *Steinernema feltiae* (2.9 lakh IJs/tree), supplied by PDBC, were applied around the trunk in the basin of the apple tree having infestation of the woolly apple aphid in the root zone in second week of August 2006. Before application of nematodes, soil was carefully removed around the tree trunk and number of aphid colonies was counted. It was 23 and 38 on these two trees. One month after application, again the colony count was taken. There was no reduction in the number of colonies in the root zone of treated trees and colonies were present on roots of the tree even in March 2007.

Table 84. Effect of application of EPNs on aerial population of the woolly apple aphid as recorded two weeks after treatment						
Treatment	Number of colonies		Colony size(cm)		Aphid coverage(cm)	
	Before	After	Before	After	Before	After
H. bacteriophora						
Treated	36	50	0.791	0.721	25.9	36.05
Control	18	25	1.064	0.944	19.2	23.6
S. feltiae						
Treated	20	14	1.163	0.775	23.25	10.85
Control	9	10	1.278	1.330	11.5	13.3

Table 85. Biological control of *Diaphania indica* on gherkins			
Treatment	Larvae/ 10 plants	Fruit damage (%)	Fruit yield (kg/ha)
Cypermethrin 0.05%	2.4[b]	0.03[a]	3920[a]
Dipel – 0.5 ml/l	2.2[b]	0.04[b]	4030[a]
Dipel – 1 ml/l	1.6[a]	0.22[b]	4120[a]
DOR *Bt* – 1g/L	3.4[c]	0.09[b]	3790[a]
S. carpocapsae – 1 billion/ha	2.7[b]	0.09[b]	3490[b]
M. anisopliae @ 1 x 10^9 spores/ml	2.5[b]	0.12[b]	3910[a]
Control	9.4[d]	1.24[c]	3050[b]
Means followed by the same letter in a column are not significantly different (P=0.05)			

Suspensions of *H. bacteriophora* (300 IJs/ml) and *S. feltiae* (200 IJs/ml) were sprayed on aphid colonies on a tree and some were maintained as control (water spray only). There was no apparent effect of *H. bacteriophora* on the apple woolly aphid, but on *S. feltiae*-treated tree, there was an indication of reduction of aphid colonies, mean colony size as well as coverage of the aphid (Table 84).

5.12. BIOLOGICAL SUPPRESSION OF PESTS OF VEGETABLES

(i) Microbial control of *Diaphania indica* infesting gherkins

IIHR

An experiment was carried out under field conditions to evaluate the efficacy of various biological control agents in controlling bud and fruit borer, *Diaphania indica* on gherkins (cv. Calypso).

The data revealed that eight sprays of the different formulations of the *Bt*, EPN and *S. carpocapsae* and *M. anisopliae* effectively checked the larval population of *D. indica* and reduced the damage to the fruits. All the microbial formulations except the EPN were equally effective in increasing the yield of fruits (Table 85).

(ii) Microbial control of diamondback moth on cabbage

IIHR

Results of an experiment was carried out at

Table 86. Efficacy of microbial against *Diaphania indica* on gherkins	
Treatment	Yield (kg/plot)
M. anisopliae @ 1 x 10^9 spores/ml	32.5
S. carpocapsae 1 billion/ha	32.7
Dipel @ 1 ml/l	33.3
DOR *Bt* @ 1g/l	31.8
Cymbush @ 2 ml/l	31.1
Control	32.2

Table 87. Efficacy of DOR *Bt* on DBM of cabbage				
Treatment	Larvae/ plant	Larval parasitism (%)	Yield (kg/ha)	Net profit (Rs/ha)
DOR *Bt* @ 1 kg/ha	1.55[a]	28.7	15288[b]	89248.57
Endosulfan 0.05%	1.83[a]	5.09	17968[a]	106807.14
Control	2.82[b]	28.2	12693[c]	76157.14

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 88. Shoot and fruit borer infestation in brinjal

Treatment	Infestation (%)		Fruit yield (kg/ha)
	Shoots	Fruits	
Bt 2kg/ha	2.0[ab]	13.6[a]	10638.1
EPN @1b/ha	2.2[b]	15.5[ab]	10046.0
EPN @2b/ha	2.1[b]	14.3[a]	10494.9
T. chilonis @ 50000/ha	1.4[ab]	17.9[b]	8637.5
Quinlaphos 0.05%	1.1[a]	16.4[ab]	10543.1
Control	5.5[c]	23.5[c]	90977.9

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 89. Evaluation of EPN against brinjal fruit borer

Treatment	Fruit damage (%)	Fruit yield (kg/ha)
EPN @1billion/ha	17.4	8070[d]
EPN @2 billion/ha	16.4	10030[b]
T. chilonis @ 50,000 adults/ha	17.3	9070[c]
Triazophos @ 530 g a.i./ha	14.8	19060[a]
Control	24.5	8020[d]

Means followed by the same letter in a column are not significantly different (P=0.05)

IIHR, Bangalore to evaluate the efficacy of various microbial control agents in controlling DBM indicated that spraying *Bt* (Dipel) @ 1ml/l five times at weekly intervals recorded the lowest larval population followed by DOR *Bt* @ 1g/l (Table 86).

MPKV

The larval population of *Plutella xylostella* in crop treated with *Bt* and endosulfan was significantly lower when compared to control and remained low even after 15 days after spray. The highest yield however was recorded in the plots treated with endosulfan followed by *Bt*. Further, it is also clear that yield obtained in the crop treated with endosulfan was significantly higher than in *Bt* treated crop. The larval parasitism was 28.7% in *Bt* treated crops compared to 5.09% in endosulfan treated crops. The larval parasitism in control field was 28.2% which is almost at par with *Bt*-treated crop (Table 87).

(iii) Biological control of brinjal shoot and fruit borer

KAU

Results of two season experiments conducted during 2005-06 and 2006-07 indicated that four applications of *Bt* @ 2 kg/ha at 10 days interval and release of *T. chilonis* @ 50,000/ha recorded the lowest incidence of the shoot borer and this was on par with quinalphos 0.05% spray. *Bt* also recorded the lowest fruit damage which was on par with EPN @ 2 billion/ha as well as quinalphos. The differences in the yield of fruits however were not significant (Table 88).

PAU

All the treatments showed lower fruit damage than control (24.5%) but the differences were not significant (Table 89). Among the biocontrol treatments, EPN @ 2 billion/ha recorded the highest yield followed by *T. chilonis* released @ 50,000/ha. Hostathion @ 1325ml/ha however was significantly the most effective recording the highest yield (Table 89).

(iv) Feeding potential of *Orius tantillus* on chilli thrips

IIHR

Orius tantillus fed upon 1-2, 2-6, and 4-11 larvae of thrips during first, second and third instar nymphal instars, respectively. Adults consumed 6-25 second instar larvae daily with a mean of 13.05 larvae. The predator survived for 7 – 22 days on *Scirtothrips dorsalis*.

(v) Microbial control of *Trialeurodes vaporariorum* using fungal pathogens

Dr.YSPUH&F

In the polyhouse, cucumber crop infested with the greenhouse whitefly was treated with conidial suspension of *B. bassiana*, *M. anisopliae*, *P. fumosoroseus* and *V. lecanii* at 10^8 conidia/ml and imidacloprid 0.00925% as a standard treatment. As compared with imidacloprid giving 67.1% kill of nymphs, the fungal preparations proved less effective. Among the fungal pathogens maximum kill of 39.3% was obtained with *P. fumosoroseus* which was on par with *M. anisopliae* and *V. lecanii*. However, *B. bassiana* proved to be ineffective.

(vi) Evaluation of DOR *Bt* against fruit borers of brinjal

KAU

Results of two season experiments revealed tht four sprays of DOR *Bt* @ 2 kg/ha was the most effective in controlling the fruit borer damage and increasing the fruit yield significantly over control (Table 90).

PAU

The experiment on evaluation of DOR *Bt* against fruit borer of Brinjal was conducted at Entomology Farm PAU, Ludhiana on variety Punjab Basmati in a plot of 50m². Four sprays of DOR-*Bt* were given at 10 days interval starting from 30 days after transplanting and it was compared with three sprays of triazophos @ 500 g a.i./ha at 15 days interval. It was found that fruit damage was minimum in chemical control (17.1%) and it was on a par with higher and medium doses of DOR- *Bt*. Fruit damage was maximum in control (27.4%) and it was on a par with lower dose (1.0 kg/ha) of DOR-*Bt* (22.4%) but was significantly higher than all other treatments. The highest marketable yield was obtained in chemical control (17,220 kg/ha) followed by higher dose of 2.0 kg/ha of *Bt* which was on par with *Bt* @ 1.5 kg/ha. (Table 91).

Table 91. Efficacy of DOR *Bt* against shoot and fruit borer of brinjal (PAU)

Treatment	Fruit damage (%)	Fruit yield (kg/ha)
DOR *Bt* 2 kg/ha	18.2[ab]	15020[b]
DOR *Bt* 1.5 kg/ha	21.8[ab]	13660[bc]
DOR *Bt* 1 kg/ha	22.4[b]	12340[cd]
Triazophos @ 500 g a.i./ha	17.1[a]	17220[a]
Control	27.4[c]	11220[d]

Means followed by the same letter in a column are not significantly different (P=0.05)

(vii) Evaluation of DOR *Bt* formulation against fruit borer on okra

PAU

Results of the experiment on evaluation of DOR *Bt* formulation against fruit borer, on okra (Punjab- 8 variety) at Entomology farm, PAU, Ludhiana revealed that the fruit damage was lowest in higher dose of DOR *Bt* (2.0kg/ha) and it was on par with medium dose (1.5 kg/ha) and chemical control.

The highest yield of 11270 kg/ha was recorded from plots of DOR-*Bt* (2.0 kg/ha), which was on

Table 90. Efficacy of DOR *Bt* against shoot and fruit borer of brinjal

Treatment	Shoot infestation (%)	Fruit infestation (%)	Fruit yield (kg/ha)
Bt 2 kg/ha	8.9[a]	17.9[a]	8347.6[a]
Bt 1.5 kg/ha	6.6[a]	24.3[ab]	5871.8[b]
Bt 1 kg/ha	9.6[a]	30.6[bc]	6052.3[b]
Malathion 0.05%	7.1[a]	23.6[ab]	6163.0[b]
Control	14.0[b]	38.9[c]	5483.1[b]

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 92. Efficacy of DOR *Bt* against fruit borer of okra

Treatment	Fruit damage (%)	Fruit yield (kg/ha)
DOR *Bt* (2.0 kg/ha)	24.0^{a}	11270^{a}
DOR *Bt* (1.5 kg/ha)	27.7^{a}	10520^{a}
DOR *Bt* (1.0 kg/ha)	37.7^{b}	8170^{b}
Endosulfan @ 300 g a.i./ha	26.4^{a}	11630^{a}
Control	41.5^{c}	6130^{b}

par with *Bt* @ 1.5 kg/ha but significantly higher than DOR-*Bt* (1.0 kg/ha) and control (Table 92). On the basis of pooled analysis of two years, it can be concluded that DOR-*Bt* @ 1.5 kg/ha can be recommended for the management of fruit borer in okra.

(x) Effectiveness of various microbial pesticides and a summer oil against *Pieris brassicae* (Lepidoptera: Pieridae) on kale / knol khol on cauliflower

YSPUH&F

A field experiment with *Bacillus thuringiensis* ssp. *kurstaki* (*Btk*) 1kg/ha, *B. bassiana* (10^{11} conidia/l), *Metarhizium anisopliae* (10^{11} conidia/l), EcoNeem Plus 0.2%, DC-Tron Plus 0.75% (summer spray oil), and dichlorvos 0.05% was laid out on cauliflower for suppression of cabbage butterfly larvae during March 2006.

Results indicate that after first spray, there was a definite reduction in larval population in insecticide-treated plots, as almost all larvae had died next day, but larvae hatched from some of the egg clusters had survived by 5-day observation. Similar trend was noticed after second spray. However, with biopesticides, reduction in larval population was evident in *B. bassiana* and *B. thuringiensis*-treated plots after 5 days of the first spray, though statistically non-significant. Significant differences were noticed in 10-day observation and low larval population of 25.3 and 43.3/plant was recorded in plots treated with *B. bassiana* and dichlorvos as against 136.3 larvae/plant in the control (Table 93). In plots treated with *B. bassiana*, *B. thuringiensis* and *M. anisopliae* as well as in the control plots, larval population remained significantly low in pretreatment count of the second spray. This indicated that natural enemy complex and abiotic factors adversely affected the larval population to a great extent. Following second treatment, there was overall reduction in the count (including control) over the respective pretreatment count in 7-day observation and it was 97.3, 89.9, 78.9 and 68.6% in plots treated with EcoNeem, dichlorvos, oil and *B. thuringiensis*, respectively, as against 52.4% in the control, but these differences were non-significant. Mean damage to foliage varied non-significantly from 36.7 to 48.3% in different treatments.

Table 93. Efficacy of some biopesticides against *Pieris brassicae* larvae on cauliflower

Treatment	Larvae/ plant 10-days after	
	I spray	II spray
Btk (1kg/ha)	113.7^{c}	16.0
B. bassiana (10^{11}conidia/l)	25.3^{a}	5.7
M. anisopliae (10^{11}conidia/l)	97.7^{bc}	20.0
EcoNeem Plus (2ml/l)	70.0^{bc}	13.0
DC-Tron Plus (0.75%)	106.3^{bc}	20.7
DDVP (0.05%)	43.3^{ab}	43.3
Control (water)	136.3^{c}	21.7

Means followed by the same letter in a column are not significantly different (P=0.05)

The presented results are not in accordance with the results obtained last year, when *Btk* and neem treatment were superior to other biocontrol treatments. From this experiment, it can be concluded that natural enemies and abiotic factors put a considerable check on survival of *P. brassicae*. *Btk* and EcoNeem Plus were effective against young larvae of the pest but older larvae were not satisfactorily controlled by the treatment.

(xi) Development of biocontrol-based IPM module against cabbage pests

SDAU

The following treatments wre tested in Department of Entomology, C. P. College of

Agriculture, S. D. Agricultural University, Sardarkrushinagar;

T_1 (IPM)

1. Use of sex pheromone traps @ 5/ ha each for *H. armigera*, *S. litura* and *P. xylostella*.
2. Mechanical collection of egg masses and first instar larval masses of *S. litura* and destruct them.
3. Six releases of *Trichogramma chilonis* @ 50,000/ha/week at initiation of eggs in the field.
4. Spray of NSKS 5%

T_2 (Chemical module)

Alternate spray with methyl oxy demeton (0.03%), quinalphos (0.05%) and endosulfan (0.07%)

T_3 Farmer's practice

T_4 Control

In the first spraying, the chemical module recorded the lowest larval population of *H. armigera*, i.e. 2.48 larvae/plant. But it was at par with T_1 and T_3 treatment. Untreated block had maximum larval population (6.48 larvae / plant). Same trend was also observed at second and third spraying. The chemical module also recorded significantly lowest larval population of *S. litura* (3.38 larvae / plant). It was significantly superior to all treatments. T1 (4.19 larvae / plant) and T3 (5.22 larvae /plant) were equally effective. Same trend was also observed at third spraying but in second spraying, results were non significant. T2 treatment had lowest larval population (3.17 larvae / plant). The IPM module was on par with chemical pesticides in reducing the larval population of *P. xylostella*

Among all the treatments, significantly lowest head damage and highest yield were recorded in chemical control. The IPM module was significantly inferior to chemical treatment (Table 94).

Table 94. Biocontrol based IPM of caterpillar pests of cabbage

Treatment	Head damage (%)	Yield (kg/ha)
IPM	35.7[c]	24400[c]
Chemical control	29.1[a]	27600[a]
Farmers' practice	32.2[b]	25400[b]
Control	41.1[d]	16400[d]

Means followed by the same letter in a column are not significantly different (P=0.05)

(xii) Evaluation of *Trichogramma brassicae* alone and in combination with *Bt* against lepidopteran pests of cole crops (cabbage/cauliflower)

The efficacy of *Trichogramma brassicae* against *P. xylostella* was compared with Bt as well as a chemical insecticide in field experiments. Following treatments were tested

1. *Trichogramma brassicae* @ 1.0 lakh/ week x 6 releases
2. *Bt* @ 1kg/ha (2 sprays)
3. *T. brassicae*@1.0 lakh/ ha & *Bt*@1kg/ha (3 releases & 1 spray)
4. Spinosad (2 sprays)
5. Untreated control.

MPKV

It is apparent from the Table 95 that all treatments significantly reduced the larval population over control. *Bt* @ 1kg/ha and spinosad were at par. The lowest curd damage was obtained with spinosad followed by *Bt* @ 1kg/ha. Highest yield was obtained with spinosad, which however was at par with *Bt* (Table 95).

SKUAS&T

The biocontrol treatments reduced the larval population as well as damage to leaves and curds. However, the chemical insecticide was more effective. Maximum yield was also obtained in the treatment with spinosad, followed by *Bt* (1 kg/ha) and *T. brassicae* (1 lakh/ha) (Table 96).

IIHR

A field trial was conducted with *T. brassicae* in September 2006 in cabbage F1 hybrid cv. Unnati for the control of the DBM. The egg parasitoid was released at weekly intervals for six weeks @ 40 – 60 thousand adults / week (equaling to a total of 300000 adults ha^{-1}) and compared with other four

Table 95. Evaluation of *Trichogramma brassicae* alone and in combination with *Bt* against *Plutella xylostella* in cabbage at MPKV

Treatment	Larvae/ plant	Curd damage (%)	Larval parasitism (%)	Yield (kg/ha)
Trichogramma brassicae @ 1.0 lakh/weed	1.2[a]	26.9[c]	21.7	1,5035[c]
DOR *Bt* @ 1 kg/ha	1.2[a]	22.5[b]	20.3	19,025[ab]
T. brassicae @ 1.0 lakh/ ha + *Bt* @ 1 kg/ha	1.2[a]	26.9[c]	20.9	1,7685[b]
Spinosad @ 250 ml/ha	1.1[a]	18.5[a]	7.3	2,0358[a]
Control	1.8[b]	29.3[d]	21.3	1,3485[d]

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 96. Evaluation of *Trichogramma brassicae* alone and in combination with *Bt* against lepidopteran pests of cauliflower at SKUAS&T

Treatment	Larvae (no./plant)	Leaves infested (%)	No. of damaged curds/m^2	Egg parasitism (%)	Larval parasitism (%)	Yield (kg/ha)
Trichogramma brassicae @ 1.0 lakh/weed	1.4	21.3	1.18	36.0	9.3	24,000
Bt @ 1 kg/ha (2 sprays)	1.9	20.8	1.21	18.3	11.3	24,200
T. brassicae @ 1 lakh/ha + *Bt* 1 kg/ha (one spray)	1.4	19.0	1.20	22.6	10.8	23,300
Spinosad 75g a.i./ha (2 spray)	0.9	10.6	0.45	8.6	7.4	28,200
Control	3.5	32.3	3.00	10.5	12.8	14,600

treatments such as two sprays of *Bt* given at fortnight interval @ 1g/l alone, two sprays of *Bt* given at fortnight interval @ 1g /l + egg parasitoid (released in six weeks @ 40 –60 thousand adults / week, equaling to a total of 300000 adults ha^{-1}), two sprays of spinosad @ 0.75ml/l given at 21 days interval, and control. All the treatments were imposed 21 days after planting. The treatments were applied on exploded plot design. Samples were drawn at weekly interval from 10 randomly-selected plants for taking observation on the population of the DBM larvae and parasitised larvae or cocoons present. Data on both total and marketable yield were recorded to determine the effect of these treatments. ANOVA was used to analyze the data.

Bt + egg parasitoid and spinosad were on par recording a mean of 1.18 larvae / plant, which were significantly superior to *Bt* alone (1.34 larvae/ plant) or parasitoid alone (1.80 larvae / plant). Nevertheless, all the treatments were significantly superior to control, which recorded a mean of 3.26 larvae / plant. *Bt* + egg parasitoid also recorded the highest yield of 46640 kg/ha, which is significantly higher than the spinosad treatment (41310 kg/ha). Interestingly, the egg parasitoid release field recorded 39640 kg/ha as against *Bt* alone (33910 kg/ha). The above treatments were significantly superior to the control, which recorded a yield of 26440 kg/ha. A similar trend was observed with marketable yield. The effect of above treatments on population of the parasitoid *Cotesia plutellae* Kurdj revealed that the activity of the parasitoid was unaffected by the egg parasitoid release compared to other treatments. This may be one of the reasons why higher yield as observed in parasitoid release field compared to *Bt* sprayed field.

(xiii) White grub (*Brahmina coriacea*) control using fungi and entomopathogenic nematodes

YSPUH&F

(a) Pathogenicity of entomopathogenic nematodes (EPN) and fungi

Steinernema feltiae @ $2x10^9$ infective juveniles (IJs) produced 20% mortality of second instar grubs of *Brahmina coriacea* within a week of treatment, which howevere did not increase further even after two weeks of treatment. Surface application of *S. feltiae* at $4x10^9$ IJ/ha in cups containing white grubs resulted in at the most 50% mortality after two weeks of treatment. Surprisingly, in none of the dead grubs, presence of nematode could be ascertained. *Heterorhabditis bacteriophora* produced a mortality of 70% 4 weeks after treatment with a dose of 2 x 10^9 IJs.

Conidial suspensions of *Beauveria brongniartii* (local isolate) and *B. bassiana* (PDBC), and commercial formulation of *B. bassiana* (10^9 conidia/g) were applied to ice cream cups each containing one second instar grub of *B. coriacea*. Maximum mortality of 70 % was obtained with the local isolate of *B. brongniartii* after 4 weeks of treatment and out of these, 60% died due to mycosis only.

In the potato farm of Department of Agriculture located at Kheradhar, near Rajgarh, heavy attack of white grubs was noticed in September. When the crop was near harvest, 12 and 95 grubs/m^2 were sampled at two locations and out of these 8.2 and 12.6% were found dead due to mycosis. Apparently healthy grubs were collected from dug out spots and brought to laboratory. After 15 days of collection, these were again examined for any disease symptoms and 22.9% of them had died due to fungal infection. Healthy grubs were transferred individually to ice cream cups containing sterilized soil. From sponge supplied by PDBC (dated 30.06.2006), EPNs *S. feltiae*, were extracted (28.7% alive) and in nematode suspension of 390 IJs/ml, 15 grubs were given dip treatment for 5 seconds and put individually in ice cream cup. In another set, 10 larvae were first given 5-second dip and then placed individually in cup in the soil; then on soil surface, nematode suspension was applied @ 40 IJs/cm^2 area (4 billion/ha). Fifteen larvae were kept untreated.

Grub mortality data recorded after 7, 14 and 30 days of treatment indicated gradual increase in mortality and maximum kill was obtained a month after the treatment, which was 46.7% in the lot given dip treatment, 50% in the lot given dip + soil application, and even in the control 33.3% grubs were found dead. In these lots, mortality due to mycosis was 13.3, 40 and 26.7%, respectively. Earlier in August, when nematodes were applied at 4 billion/ha on soil surface, mortality obtained was 50%. It was surprising to note that in none of the dead grub, nematodes were present.

(b) Field evaluation of some fungal preparations and entomopathogenic nematodes against white grubs in potato crop

Attempt was made to culture the local isolate of *B. brongniartii* on well rotten FYM after autoclaving it, with the aim of making fungus-enriched FYM for field application. However, we failed to get good growth of the fungus.

In the last week of June, *B. bassiana* (PDBC) and *B. brongniartii* (local isolate) and in last week of July, *B. bassiana* (Daman), *Heterorhabditis bacteriophora* and *Steinernema feltiae* were applied in 4m x 3m plots (3 replicates/ treatment) at Shilaroo (Government Potato Farm) by drenching the standing crop. Fungi were applied at 10^{14} conidia/ha, while EPNs were applied at $2x10^9$ IJs/ha. By mid of September, when crop was harvested, white grub population/m row (5 spots in each plot) was recorded; in addition to it, per cent damage on harvested tubers was also recorded. The white grub population per metre in treated plots

Table 97. Effect of application of entomopathogenic fungi (10^{14}/ha) and nematodes ($2x10^9$/ha) on population of white grubs and damage to tubers		
Treatment	Grub population/m	Tuber damage (%)
B. brongniartii	2.2	12.7
B. bassiana (PDBC)	5.4	41.4
B. bassiana (Daman)	4.2	15.8
H. bacteriophora	2.7	7.6
S. feltiae	4.9	32.3
Control	7.3	36.4

was lesser (2.2-5.4/m row) than that in the control (7.3 grubs/m) but all these values did not differ significantly in statistical test. Minimum population was recorded in *B. brongniartii*-treated plots. Minimum tuber damage was recorded in *H. bacteriophora* (7.6%) and highest in *B. bassiana* indicating the ineffectiveness of the latter (Table 97).

5.13. BIOLOGICAL SUPPRESSION OF WEEDS

(i) Survey for the natural enemies of *Cyperus rotundus*

AAU(J)

The survey for the occurrence of natural enemies of *C. rotundus* was carried out at Jorhat, Golaghat and Nagaon district. During the year 2007 a lepidopteran borer was observed in the Experimental Farm, Dept. of Horticulture, Assam Agricultural University, Jorhat and at Bagori, Nagaon district, which is being identified.

PAU

Cyperus rotundus samples were collected from different areas at fortnight interval from July to October 2006. These were processed for isolation of fungi on potato dextrose agar under aseptic conditions. *Fusarium* spp. and *Aspergillus* spp. were isolated to the extent of 2-3% during the period.

NRCWS

Surveys were conducted during 2006 in Jabalpur for the collection of promising weed pathogens against *C. rotundus*. Two leaf spot diseases were observed in the month of August and one rust disease was observed from September 2006 to February 2007. Maximum damage in *C. rotundus* due to rust disease in nature was noticed in the months of September-October. Two fungi were isolated from leaf spot, one was identified as *Colletotrichum dematium* and another is yet to be identified. The pathogenicity was proved for both the leaf spot fungi.

The rust fungus was identified as a species of *Puccinia*. On artificial inoculation in pot cultured *C. rotundus* plants, fungus successfully produced disease symptoms of minute, brown coloured uredinia after 8 days of inoculation. Inoculation of rust significantly reduced the tiller number, fresh weight of tillers and roots, and number, fresh and dry weight of nuts (Table 98). This damage potential was recorded in the months which were less favourable to disease development and much more damage of *C. rotundus* is expected in favourable months, i.e. September-October when 100% damage was observed in natural conditions due to rust disease.

The following insect species were recorded on *C. rotundus*:

1. *Bactra venosana* (Tortricid moth)

Table 98. Biomass reduction in *Cyperus rotundus* due to rust inoculation under pot experiments	
Parameter	Reduction (%)
Tiller number	25.0
Fresh weight of shoot	32.0
Fresh weight of root	12.9
Number of nuts	18.6
Fresh weight of nuts	26.0
Dry weight of nuts	25.0

Table 99. Efficacy of *Metarhizium anisopliae* against *Holotrichia longipennis* on soybean		
Treatment	Plant mortality (%) after 80 DAS	Grain yield (kg/ha)
M. anisopliae spore dust @ 1 x 10^{14} conidia/ha	25.0	1110
Chlorpyriphos 20 EC 0.20 kg a.i./ha	27.3	1083
Chlorpyriphos 20 EC 0.40 kg a.i./ha	17.3	1610
Chlorpyriphos 20 EC 200 g.a.i./ha + *M. anisopliae* (5 x 10^{13} conidia/ha)	21.4	1333
M. anisopliae spore dust@ 5 x 10^{13} conidia/ha at sowing + one dose at 22 days after MBE	28.9	1055
Imidacloprid 200SL @ 0.048 kg. a.i/ha at sowing time	13.1	1805
Imidacloprid 200 SL @ 0.048 kg a.i./ha + M. anisopliae spore dust @ 5 x 10^{13} conidia/ha at sowing	11.7	1999
Untreated control	49.9	667

2. *Bactra minima* (Tortricid moth)
3. *Psalis* sp.
4. *Athesapeuta cyperi* (a weevil)
5. *Rhopalosiphum nymphacae* (Aphid)

None of the species was however found effective in controlling the weed in the field. *Bactra minima* infestation ranged from 10 to 19% during June to October. It was 19% in July and 15% in September 2006. After egg laying on the plant, larvae tunneled into the upper portion of shoot. About 10-12 days were required to kill the plants and 2-3 plants were infested before pupation on the basal part of the plant. It was observed that the insect was not able to kill the plant completely as after killing of main shoots, plants produced side shoots after 7-9 days. Adult longevity was recorded as 6-14 days. A female was able to produce 70 to 150 eggs during its life.

3.14. BIOLOGICAL SUPPRESSION OF WHITE GRUBS

(i) Biological control of white grub, *Holotrichia longipennis* with *M. anisopliae* in soybean (cv. VLS-21) during *Kharif* 2005-06

Results of the field experiments conducted at the Research Station, Gaja (Dist. Tehri Garhwal) on Soybean (Var. VLS-21) indicated that *M. anisopliae* spore dust (5 x 10^{13} conidia/ha) in combination with imidacloprid 200 SL @ 0.048 kg a.i./ha proved to be the most effective and significantly superior over other treatments by registering lowest plant damage (11.72%) and highest grain yield (19.99 q/ha) (Table 99). *Metarhizium anisopliae* spore dust applied alone at $1x10^{14}$ and $5x10^{13}$ conidia/ha was not found promising in controlling the white grubs.

(ii) Biological suppression of white grub, *H. longipennis* through *Beauveria bassiana* in soybean (cv. VLS-21) during *kharif* 2005

Spore dust of *Beauveria bassiana* @ 5 x 10^{13} spores/ha + imidacloprid 200 SL @ 0.0248 kg a.i./ha proved most effective by registering lowest plant damage (10.3% plant mortality) and highest grain yield (20.27 q/ha). *Beauveria bassiana* spore dust applied alone at both the doses, i.e. 1 x 10^{14} and 5 x 10^{13} conidia/ha was not found effective.

(iii) Studies on bioefficacy of a local strain of *Steinernema glaseri* against third instar grubs of *H. longipennis* under laboratory conditions

Laboratory experiments showed that *S. glaseri* could produce 90% mortality of third instar larvae of *H. longipennis* within seven days when applied at a dose of 1500 IJs/grub. Microscopic examination of the smears confirmed the presence of IJ in the cadavers.

3.15. BIOLOGICAL SUPPRESSION OF PESTS IN POLYHOUSES

(i) Evaluation of fungal pathogens against thrips on capsicum

MPKV

The experiment was conducted under polyhouse conditions in Hi-Tech Floriculture Project, College of Agriculture, Pune on capsicum (var. Bombay). The fungal pathogens tested were: *M. anisopliae* @ 10^{10} conidia / l; *V. lecanii* @ 10^{10} conidia / l; *B. bassiana* @ 10^{10} conidia / l; *Hirsutella thompsonii* @ 10 g / l; insecticide check (Methyl demeton 0.05%) and untreated control. Among the fungal pathogens tested, *M. anisopliae* was comparatively more effective than others. However, *B. bassiana* and *H. thompsonii* were found equally effective in reducing thrip number and increasing the yield (Table 100).

Table 100. Efficacy of fungal pathogens against thrips on capsicum in polyhouses

Treatment	Thrips* /3 leaves	Yield (kg / replication)
M. anisopliae	30.0^{b}	865.3^{b}
V. lecanii	34.7^{b}	736.8^{c}
B. bassiana	35.5^{b}	862.1^{b}
H. thompsonii	37.4^{b}	836.3^{b}
Methyl demeton	4.6^{a}	951.5^{a}
Control	82.6^{c}	586.5^{d}

* 7^{th} day post spray

Means followed by the same letter in a column are not significantly different (P=0.05)

(ii) Evaluation of fungal pathogens for the control of thrips on gerbera plants

KAU

Survey conducted in Vellanikkara area shows that the pests present in Polyhouses on Gerbera and Croton plants were aphids, mealy bugs, scales, mites and thrips. Gerbera plants were found severely affected by thrips (*Frankliniella* sp.). So

Table 101. Efficacy of some fungal pathogens against thrips on gerbera

Treatment	Thrips/ 7 days leaf after spray	
	I	II
Verticel	1.2^{b}	0.2^{b}
Verticillium lecanii	1.6^{b}	0.3^{b}
Hirsutella thompsonii	0.7^{b}	0.4^{b}
Metarhizium anisopliae	2.0^{b}	0.6^{b}
Beaveria bassiana	1.8^{b}	0.9^{b}
Imidacloprid 0.006%	1.1^{b}	0.6^{b}
Control	4.9^{a}	4.3^{a}

Means followed by the same letter in a column are not significantly different (P=0.05)

the fungal pathogens were tried for the control of thrips on gerbera.

The data on the population of thrips recorded seven days after the two sprays indicated that all the fungal pathogens were equally effective in reducing the population of thrips and on par with the chemical insecticide (Table 101).

NCIPM

An experiment was conducted under polyhouse conditions at Ram Nagar (Uttaranchal) for the management of white fly in the polyhouse in the last week of November 2006.

Two sprays of *V. lecanii* supplied by PDBC for the control of whitefly in gerbera was done at the rate of 1×10^{6} CFU/ml. After first spray population of whitefly had gone down but again the population increased very fast. When second

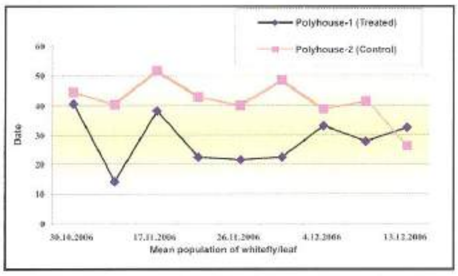

Fig. 16. Effect of application of *Verticillium lecanii* on whitefly infestation in gerbera

Modules	No. of larvae / plant		Bollworm damage (%)				Yield (Kg/ha)
	H. armigera	*E. vitella*	Fruiting bodies	Open boll	Locule	Inter locule	
Bt – BIPM	0.10^{a}	0.03^{a}	1.10^{a}	0.4^{a}	0.18^{a}	0.23^{a}	1960^{a}
Non *Bt* – BIPM	0.30^{c}	0.11^{b}	2.40^{c}	0.8^{c}	0.61^{c}	0.87^{c}	1685^{c}
Bt – SP	0.20^{b}	0.04^{a}	1.50^{b}	0.6^{b}	0.24^{b}	0.29^{b}	1900^{b}
Non *Bt* – FP	0.70^{d}	0.60^{c}	4.80^{d}	1.8^{d}	1.41^{d}	1.45^{d}	1488^{d}

Table 48. Incidence of bollworms and damage in different modules at Puthur (2006 -2007)

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 49. Effect of bio-intensive pest management practices on pest complex, natural enemies and yield of *Bt* cotton during 2006-07 at College of Agriculture, Dhule

Treatment	Sucking pest population/ 3 leaves				NEs population (No. / plant)		Bollworm damage (%)		Yield of kapas (kg/ha)
	Aphids	Jassids	Thrips	Leaf miner	Coccinellids	*C. carnea*	Squares	Bolls	
Bt cotton with BIPM package	50.8	16.2^{c}	3.4^{b}	2.6	3.7	2.1^{a}	0.0^{a}	4.6^{b}	2400
Non *Bt* cotton with BIPM package	46.0	12.5^{c}	4.2^{b}	3.2	3.9	1.4^{b}	2.5^{b}	3.2^{a}	2500
Bt cotton with standard package	43.0	7.2^{b}	1.2^{a}	3.8	3.6	2.4^{a}	0.0^{a}	2.6^{a}	2450
Non *Bt* cotton with standard practice	41.0	2.1^{a}	1.2^{a}	3.8	3.5	1.2^{b}	10.2^{c}	3.2^{a}	2160

Means followed by the same letter in a column are not significantly different (P=0.05)

Bollworm damage

The per cent fruiting body damage in different modules was in the order of *Bt* BIPM < *Bt* SP < Non *Bt* BIPM < non-*Bt* SP. Similar trend was noticed in case of open boll, locule and inter locule damage (Table 48). Hence the *Bt*-BIPM plots recorded lowest number of bollworms and lowest extent of damage.

Yield

The *Bt* cotton protected with IPM module recorded more yield (1960 kg / ha), whereas non-*Bt* SP module recorded 1488 kg / ha. *Bt* cotton under BIPM or SP performed better in reducing the bollworm damage and gave higher seed cotton yield.

MPKV

The data on sucking pests revealed no significant differences in population of aphids and leaf miners between the treatments. Population of leaf hoppers and thrips were higher in BIPM (both *Bt* and non-*Bt*) than in standard practice (Table 49). *Bt* cotton recorded higher population of coccinellids than non-*Bt* cotton. Since the damage to squares and bolls were very low and the differences in seed cotton yield being not significant no meaningful conclusion can be drawn.

PAU

The experiment on BIPM of *Bt* Cotton was conducted at Karni Khera (District Ferozepur) by taking three *Bt* and three Non- *Bt* hybrids namely RCH 134 *Bt*, MRCH 6301 *Bt*, Ankur 651 *Bt*, RCH 134 Non-*Bt*, MRCH 6301 non-*Bt* and Ankur 651 non-*Bt* during *Kharif* 2006-2007. The data revealed that population of white flies, jassids on *Bt* hybrids was marginally lower in BIPM plots than the non-*Bt* BIPM plots. There were, however, no significant differences in the spider population in both non-*Bt*

Table 50. Pest incidence in BIPM of *Bt* cotton at village Karni Khera, Punjab during 2006.												
Organism/ 3 leaves	Insect number / 3 leaves											
	RCH 134				MRCH 6301				Ankur 651			
	Bt		Non-*Bt*		*Bt*		Non-*Bt*		*Bt*		Non-*Bt*	
	SP	BIPM	SP	BIPM	SP	BIPM	SP	BIPM	SP	BIPM	SP	BIPM
Leafhopper	2.3	1.6	2.1	2.0	2.1	2.3	2.1	1.8	2.1	1.9	2.4	1.9
Whitefly	1.9	1.8	1.6	1.7	1.6	2.0	1.9	1.8	2.1	2.0	2.3	1.9
Spider	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Predators	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.2
Seed cotton (kg/ha)	3510	3420	3150	3090	3020	3010	2850	2710	2400	2220	2050	2000

Table 51. Status of pest complex in different *Bt* cotton hybrids and their non-*Bt* counterparts in Warangal district							
Cultivar	Sucking pests/3 leaves			Damage by bollworms (%)			Seed cotton yield (kg/ha)
	Aphids	Jassids	WF	Square	Boll	Locule	
RCH 2 *Bt*	5.8[b]	7.1[b]	10.1[b]	6.4[f]	1.2[h]	19.2[g]	3174[a]
RCH 2 non-*Bt*	2.3[h]	3.6[d]	7.2[d]	21.3[b]	7.2[d]	22.1[e]	2651[b]
RCH 20 *Bt*	6.9[a]	8.7[a]	12.2[a]	5.18[g]	2.1[f]	20.1[f]	2723[b]
RCH 20 non-*Bt*	5.7[b]	4.2[d]	8.1[c]	19.1[d]	8.42[b]	25.6[a]	2241[c]
Bunny *Bt*	3.2[f]	4.2[d]	5.6[e]	4.22[h]	0.9[i]	23.6[c]	2862[b]
Bunny non-*Bt*	2.9[g]	3.6[d]	4.2[f]	20.4[c]	6.7[e]	22.7[d]	2415[c]
Mallika *Bt*	4.7[d]	5.4[c]	7.1[d]	6.21[f]	2.2[f]	17.2[h]	3267[a]
Mallika non-*Bt*	4.2[e]	3.9[d]	5.7[e]	22.1[a]	7.8[c]	19.1[g]	2431[c]
ProAgro 368 *Bt*	4.9[d]	6.9[b]	8.2[c]	5.23[g]	1.9[g]	24.5[b]	2837[b]
ProAgro 368 non-*Bt*	5.2[c]	5.2[c]	3.5[g]	18.7[e]	9.2[a]	25.6[a]	1958[d]
Means followed by the same letter in a column are not significantly different (*P*=0.05)							

hybrids. The population of predators (*C. carnea, Geocoris* sp., *Zelus* sp. and pirate bug) on *Bt* hybrids at Karni Khera on IPM and BIPM practices was 0.1 and 0.2 on RCH 134 *Bt* and MRCH 6301*Bt* and 0.1 and 0.1 on Ankur 651*Bt*. The mean population of predators on non-*Bt* hybrids at Karni Khera on standard practices and BIPM practice was 0.2 and 0.1 on RCH 134 non- *Bt*; 0.2 and 0.2 on MRCH 6301 non-*Bt* and 0.1 and 0.2 on Ankur 651 non-*Bt* (Table 50).

It can be concluded that the sucking pests on *Bt* as well as non *Bt* cotton can be managed by using only BIPM package. There was no significant difference in yield between the *Bt* and non-*Bt* hybrids as the pest population was low, however, highest yield was recorded in RCH 134 *Bt* followed by MRCH 6301 *Bt* and Ankur 651 *Bt* hybrids.

(ii) Natural enemy complex of pests in *Bt* & non-*Bt* cotton varieties & hybrids

ANGRAU

The experimentation was taken up in Gorrupadu and surrounding villages of Warangal district. A total of 5 *Bt* cotton hybrids, viz. RCH-2 and 20, Bunny, Mallika and ProAgro-368 were observed for the incidence of sucking pests, damage of boll worms, extent of parasitism by *T. chilonis,* abundance of predatory fauna such as chrysopids, coccinellids, predatory bugs and spiders and yield of seed cotton during the experimentation. The data from the non-*Bt* counter parts of the above *Bt* hybrids was also recorded for the purpose of comparisons.

Perusal of the data revealed that (Table 51 & 52) the *Bt* hybrids varied differently with their

Table 52. Abundance of natural enemies in different *Bt* cotton hybrids and their non-*Bt* counterparts in Warangal district

Cultivar	Mean populations of natural enemies/ 25 plants				Parasitisation by
	C. carnea	Coccinellids	Bugs	Spiders	*T. chilonis* (%)
RCH 2 *Bt*	19.2	22.7	12.3	9.2	1.9
RCH 2 non-*Bt*	21.7	14.5	7.5	8.7	18.7
RCH 20 *Bt*	22.5	17.2	8.9	14.5	2.3
RCH 20 non-*Bt*	17.7	15.4	9.1	12.7	19.4
Bunny *Bt*	16.5	27.9	16.2	18.5	1.7
Bunny non-*Bt*	21.2	23.4	14.7	16.4	14.3
Mallika *Bt*	12.8	19.8	13.8	8.9	2.5
Mallika non-*Bt*	19.7	25.6	9.2	10.2	21.2
ProAgro 368 *Bt*	22.6	14.2	12.7	12.3	1.8
ProAgro 368 non-*Bt*	18.4	18.1	9.4	14.2	15.5

Table 53. Population of natural enemies in different cotton cultivars (2006-07)

Treatment*	Mean population of natural enemies per 25 plants					Parasitisation
	C. carnea	*C. sexmaculatus*	*Geocoris* sp.	Staphylinids	*Rogas* sp.	by *T. chilonis* (%)
Bt with SD	76.7	65.8	27.8	8.0	2.2	15.4
Bt without SD	73.2	60.0	24.3	6.5	1.5	14.5
G-Cot H- 8	49.2	43.0	9.0	4.3	2.5	20.6
G Cot H-10	53.5	46.7	11.2	5.0	3.5	23.0

* SD= seed treatment with imidacloprid

non-*Bt* counterparts and also among themselves. Maximum number of aphids was recorded in RCH 20 *Bt* followed by RCH 2 *Bt* and minimum on Bunny non-*Bt* . Similarly, maximum number of leafhoppers was recorded in RCH 20 *Bt* and minimum on Bunny non-*Bt*. The whitefly incidence was maximum in RCH 20 *Bt* and minimum in ProAgro 368 non-*Bt* hybrid. The *Bt* hybrids harboured more sucking pests fared better in suppressing square and boll damage as compared to their non-*Bt* counterparts.

Maximum egg parasitism by *T. chilonis* (21.2%) was noticed in Mallika non-*Bt* followed by 19.4% in RCH 20 non-*Bt*. In *Bt* hybrids the overall egg parasitism by *T. chilonis* was found to be less, ranging from 1.7 – 2.5% . The abundance of chrysopids was maximum in ProAgro 368 *Bt* while the coccinellids were found to be more in Bunny *Bt*. The predatory bugs and spiders were also found to be maximum in Bunny *Bt*.

AAU(A)

The experimentation was taken up at the Agronomy Farm of B. A. College of Agriculture. RCH-2 *Bt* and G-cot H-8 and G-cot H-10 both non Bt hybrids were observed for the incidence of sucking pest, damage of boll worms, extent of parasitism by *T. chilonis*, abundance of predatory fauna such as chrysopids, coccinellids, predatory bugs and spiders and yield of seed cotton.

Population of natural enemies (Table 53) was relatively higher in *Bt* cotton irrespective of the seed treatment while a relatively lower population of various bioagents was recorded from both the local hybrid cultivars. Interestingly, higher parasitism in bollworm eggs by *T. chilonis* (20.6 to 23.0%) was recorded in non-*Bt* cultivars as against 14.4 to 15.4% in *Bt* cultivars.

Bt cotton seed treated with imidacloprid registered significantly lower incidence of sucking pests as compared to the other treatments evaluated. *Bt* cotton without seed treatment was found better than non-*Bt* cotton hybrids without seed treatment. Similar trend was observed with reference to bud and boll damage. *Bt* cotton (RCH-2) + imidacloprid seed treatment recorded minimum (0.8 to 0.9%) locule damage by *E. vittella* and *P. gossypiella*

Table 54. Incidence of insect pests and seed cotton yield in *Bt* and non *Bt* Hybrids (2006-07)

Treatment	Sucking pests / 15 leaves			Damage by bollworms (%)				Yield (kg/ha)
	Aphid	Jassid	Whitefly	Bud	Boll	Locules		
						E. v.	*P. g.*	
RCH 2-*Bt* with SD*	18.8^{d}	3.7^{d}	3.0^{d}	1.1^{d}	1.8^{d}	0.8^{c}	0.9^{b}	2483^{a}
RCH 2- *Bt* without SD*	30.7^{c}	7.9^{c}	4.4^{c}	2.2^{c}	3.4^{c}	1.2^{c}	1.2^{b}	2350^{a}
G Cot Hybrid 8	55.6^{a}	11.6^{a}	6.0^{a}	7.4^{a}	9.6^{a}	12.3^{a}	21.8^{a}	1683^{b}
G Cot Hybrid 10	52.3^{b}	10.2^{b}	5.3^{b}	6.1^{b}	7.7^{b}	10.6^{b}	20.8^{a}	1903^{b}

E.v.= Earias vittella, P. g.= Pectinophora gossypiella

*SD= seed treatment with imidacloprid

Means followed by the same letter in a column are not significantly different (P=0.05)

whereas it was 1.2% in case of *Bt* cotton without seed treatment. However, both the treatments were at par with each other (Table 54). Maximum seed cotton yield was harvested in *Bt* cotton + imidacloprid seed treatment followed by *Bt* cotton without Gaucho seed treatment. Both the treatments registered higher yields over non-*Bt* cultivars.

PAU

The experiment was conducted at the Entomological Research Farm, PAU, Ludhiana. Four *Bt* hybrids namely MRCH 6301, MRCH 6304, RCH 134, RCH 317 and their non-*Bt* counterparts were grown in a plot size of 500 m^2 each with three replications.

When data was pooled the highest jassid population (1.0 nymph/ 3 leaves) was recorded in MRCH 6301 *Bt* and it was significantly higher than all other cultivars except RCH 134 (non-*Bt*) and RCH 317 (non-*Bt*). Lowest population (0.3 nymphs/ 3 leaves) was recorded in RCH 317 *Bt* and it was significantly lower than RCH 134 (non-*Bt*) and MRCH 6301*Bt* but on par with other cultivars (Table 55).

The whitefly population remained low during the season with no significant differences among various cultivars. The *Bt* cultivars remained free from bollworm incidence. However, on non- *Bt* hybrids, the incidence of spotted bollworms was recorded. *H. armigera* did not appear during the season. The incidence of spotted bollworm among the intact fruiting bodies varied significantly among the cultivars on all the dates of observations. When data of all dates were pooled, the bollworm incidence in non-*Bt* hybrids (15.0 to 18.2%) was significantly higher than *Bt* hybrids where incidence

Table 55. Occurrence of pests and their natural enemies in different *Bt* and non-*Bt* hybrids of cotton in Punjab

Treatment	Number/ 3 leaves			
	Leaf hoppers	Whiteflies	Square damage (%)	Yield (kg/ha)
RCH 134 *Bt*	0.4^{ab}	1.0	0.0^{a}	2860^{a}
RCH 317 *Bt*	0.3^{a}	0.7	0.0^{a}	2530^{b}
RCH 134 Non-*Bt*	0.9^{bc}	1.1	16.8^{c}	1960^{d}
RCH 317 Non-*Bt*	0.7^{abc}	0.7	18.2^{d}	1740de
MRCH 6304 *Bt*	0.4^{ab}	0.9	0.0^{a}	1680^{e}
MRCH 6304 Non- *Bt*	0.4^{ab}	1.6	15.0^{b}	2280^{c}
MRCH 6301Non- *Bt*	0.4^{ab}	0.9	16.5^{c}	1520^{e}
MRCH 6301 *Bt*	1.0^{c}	1.6	0.0^{a}	2260^{c}

Means followed by the same letter in a column are not significantly different (P=0.05)

was nil. Among Non *Bt* hybrids, lowest incidence was recorded in MRCH 6304 (non-*Bt*) and it was significantly lower than other non-*Bt* hybrids. Significantly higher incidence was recorded in RCH 317 (non-*Bt*) than all other cultivars.

Incidence of spotted bollworms among green bolls was also recorded only on non- *Bt* hybrids and *Bt* hybrids were free from its attack. Among the non-*Bt* hybrids there was no significant difference in bollworm incidence among green bolls and it varied from 6.0 % to 6.3 %. Population of natural enemy complex including *Chrysoperla* spp., *Zelus* spp. *Geocorus* spp. and spiders varied from 0.8 to 0.9 per plant and there was no significant difference among various cultivars.

The yield of seed cotton in *Bt* hybrids was significantly higher than non-*Bt* hybrids. The highest yield was recorded in RCH 134(*Bt*) and it was significantly higher than all other cultivars. The lowest yield was recorded in MRCH 6301 (non-*Bt*) and it was significantly lower than all other cultivars except-MRCH 6304 (non-*Bt*) and RCH 317(non-*Bt*).

(iii) Enhancement of natural enemy population in cotton by habitat manipulation

PAU

The experiment on enhancement of natural enemy population in cotton by habitat manipulation was conducted at Entomological Farm, PAU, Ludhiana.

The following three module (M) were tested:

M_1 - **Habitat management**: Four paired rows of cotton interspersed with one paired row consisting of one row of cowpea and one row of marigold. One paired row of sorghum was grown all- round the plot as border crop. Eight releases of *T. chilonis* @150000 / ha were made at weekly interval coinciding with egg laying by boll worm from July to October.

M_2 - **BIPM practice**: Twelve releases of *T. chilonis* @1,50,000/ha at weekly interval from July to October. Since, *H. armigera* and *S. litura* did not appear on the crop, no NPV spray was given.

M_3 - **Insecticidal control**: One spray of imidacloprid 200SL @100ml/ha on 30-8-06 for the control of cotton jassid. One spray of decamethrin 2.8EC @ 400ml / ha on 9-8-06 and second of endosulfan 35 EC @ 2.5l / ha on 16.9.06 against spotted bollworm (*Earias* sp.).

The data revealed that leaf hopper population was significantly lower (1.8nymphs/ 3leaves) in the insecticidal control plot as compared to habitat management and BIPM plots. The white fly remained below ETL (18 adults/ 3leaves) and the mean whitefly population did not vary significantly among the treatments (Table 56). There was no incidence of *H. armigera* and *S. litura* on cotton during 2006. However, spotted bollworm appeared as an important pest and its incidence was significantly lower in insecticidal treatment plot than habitat management and BIPM. Bollworm incidence in habitat management was on par with BIPM (Table 56).

Similarly significantly lower bollworm incidence and boll damage among green bolls was recorded in insecticidal control plot than habitat

Table 56. Effect of crop habitat diversity on the occurrence of pests and natural enemies population in cotton in Punjab during 2006

Treatment	population/ three leaves		Square damage (%)	Yield (kg/ha)	Natural enemy per plant	Yield (kg/ ha) 2005-06 pooled	Mean natural enemy per plant (2005-06 pooled)
	Leaf hoppers	Whitefly					
Habitat management	4.9b	1.9	10.6b	1080b	1.2	1100b	1.0
BIPM	4.9b	2.2	11.4b	1010b	1.0	1060b	0.8
Insecticidal control	1.8a	1.6	6.6a	1290a	0.1	1390a	0.1

Means followed by the same letter in a column are not significantly different (*P*=0.05)

management and BIPM, the latter two being on par (Table 56). Natural enemies population consisting of *Chrysoperla* sp.; *Zelus* sp., *Geocoris* sp., and spiders was higher in habitat management plot followed by BIPM and was lowest in insecticidal control (Table 56). Highest seed cotton yield was was recorded in insecticidal control plot and it was significantly higher than habitat management and BIPM the later two being on par (Table 56).

ANGRAU

The experiment was laid out at ARS, Warangal during *Kharif* 2006-07. The following crop habitat module (M) were maintained for the purpose of experimentation.

M1: - Four paired rows of cotton interspersed with one paired row consisting of cowpea and one row of marigold. Al round the plot, one paired row of sorghum was raised as border crop. Single release of *C. carnea* @ 5000/ha was made synchronizing with appearance of sucking pests and release of *T. chilonis* @ 1,50,000/ha/week was done coinciding with egg laying by boll worm. Three such releases were made.

M2: - Cotton without intercrop/border crop was maintained under BIPM practices

M3: - Cotton without intercrop/border crop was maintained with Farmer's practices (FP).

The results of the expeiment revealed that maximum number of aphids, leaf hoppers and white flies were noticed in M3, while minimum was noticed in M1, where the cotton was interspersed with cowpea and marigold with a border row of jowar (Table 57.). Least square and boll damage was recorded in Module M 1 while maximum square and boll damage was recorded in M3 where cotton was grown with farmer's Practice module.

Maximum egg parasitism by *T. chilonis* and more number of predatory fauna of chrysopids, coccinellids, predatory bugs and spiders were noticed in M1 module while these predatory populations were least in M3 where cotton was grown under farmer's practice module with chemical pesticides (Table 58). Seed cotton M1 also recorded maximum seed cotton yield of 2326 kg/ha while M2 recorded 1025 kg/ha. In M3 where cotton was grown under farmer's practice module minimum yield of 1158 kg/ha was recorded.

Results of the experimentation has proved that when cotton was grown interspersed with cowpea and marigold with a border row of sorghum there was enhancement in the population of natural enemies resulting in reduced levels of sucking pest populations and damage by boll worms with increased yields and net returns.

Table 57. Impact of crop habitat manipulation on the occurrence of pests on cotton in Andhra Pradesh

Crop module	Sucking pests/3 leaves			Damage by boll worms (%)			Yield
	Aphids	Jassids	WF	Square	Boll	Locule	(kg/ha)
Cotton+IC+BC	2.3[a]	0.9[a]	5.3[a]	3.9[a]	0.2[a]	21.2[b]	2326[a]
Cotton+BIPM	4.9[b]	3.4[b]	8.5[b]	4.2[b]	1.9[b]	20.3[a]	1052[b]
Cotton+FP	7.8[c]	4.2[c]	10.3[c]	6.5[c]	2.7[b]	29.7[c]	1158[b]

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 58. Abundance of natural enemies in different crop habitat manipulation modules

Crop module	Mean Populations of natural enemies per 25 plants				Parasitism by *T. chilonis*
	C. carnea	Coccinellids	Bugs	Spiders	
Cotton+IC+BC	23.5	18.5	16.1	12.1	2.71
Cotton+BIPM	12.3	9.7	7.5	5.4	1.83
Cotton+FP	0.8	0.3	0.3	2.7	0.87

Table 59. Incidence of insect pests and yield of cotton under crop habitat diversity at Anand								
Module	Sucking pests / 15 leaves			Damage by bollworms (%)				Seed cotton yield (kg/ha)
	Aphids	Leaf hoppers	Whiteflies	*E. vittella*		Locules		
				Bud	Boll	*E. v.*	*P. g.*	
1	13.4[d]	3.1[c]	2.7[c]	3.3[d]	5.9[d]	12.2[c]	12.8[d]	1969[a]
2	23.4[c]	5.0[b]	4.4[b]	4.9[c]	8.2[c]	13.0[c]	15.6[c]	1864[a]
3	26.4[b]	4.9[b]	3.2[c]	7.6[b]	10.7[b]	15.0[b]	23.6[b]	1781[a]
4 (control)	105.1[a]	12.6[a]	9.2[a]	18.0[a]	29.7[a]	31.3[a]	31.5[a]	1278[b]

E.v.= Earias vittella, P. g.= Pectinophora gossypiella
Means followed by the same letter in a column are not significantly different (P=0.05)

Table 60. Population of natural enemies in different treatments under habitat manipulation (Pooled of 2005-06 and 2006-07)						
Module	Mean population of natural enemies/25 plants					Parasitism by
	C. carnea	*C. sexmaculatus*	*Geocoris*	*Staphylenids*	*Rogas*	*T. chilonis* (%)
1	68.7	61.0	24.8	7.0	3.2	17.8
2	40.1	51.2	21.0	5.4	2.5	14.4
3	15.9	16.7	8.5	2.4	1.0	5.1
4 (control)	21.4	42.5	14.9	4.3	1.9	10.7

AAU(A)

The experiment was conducted in agronomy farm, B. A. College of Agriculture, Anand. Agro-climatic zone-3 during the 2005-06. The following modules were evaluated:

M1: Treatment of cotton seeds with *Trichoderma* @ 5.0 g / kg, cotton interspersed with *Cassia occidentalis* (6:1) + 10 % planting of maize and zinnia + one round of *T. chilonis* @ 1,50,000 + 5000 larvae of *C. carnea* (one release).

M2 : Treatment of cotton seeds with *Trichoderma* @ 5..0 g / kg, cotton interspersed with *Cassia occidentalis* (6:1) + 10 % planting of maize and zinnia.

M3 : Insecticidal control

M4 : Untreated control

Data presented in Table 59 indicates that the sucking pest population was significantly low in M1 [IPM + *T. chilonis* + *C. carnea* (6:1)] as compared to the other treatments evaluated. Incidence of *E. vittella* on buds and bolls was also found to be lower in habitat manipulations. Maximum seed cotton yield (1969 kg/ ha.) was harvested from the plots with *Trichoderma* seed treatment + cotton interspersed with *C. occidentalis* + planting of maize and zinnia @ 10% + one release of biocontrol agents followed by IPM (6:1) treatment. Both the treatments produced significantly higher yields over untreated check (Table 59).

Greater numbers of natural enemies (Table 60) were recorded from M1 indicating beneficial effect of habitat manipulation. The parasitism of bollworm eggs by *T. chilonis* as well as the occurrence of predators were also higher in habitat manipulation treatments.

(iv) Kairomones to increase the efficiency of trichogrammatids

UAS(D), Raichur in collaboration with PDBC

This experiment was conducted on NCS-145 (Bunny cotton hybrid) at the Regional

Table 61. Incidence of *Helicoverpa armigera*, recovery of Trichogrammatids and seed cotton yield during *Kharif* 2006-07

Module	Recovery of *T. chilonis* (%)	Fruiting bodies damage (%)	Seed cotton yield (kg/ha)
1	19.55[a]	14.25[b]	1512[ab]
2	28.79[b]	12.90[a]	1605[a]
3	12.82[c]	15.27[bc]	1467[bc]
4 - control	8.91[d]	17.62[c]	1395[c]

Means followed by the same letter in a column are not significantly different (P=0.05)

Agricultural Research Station, Raichur with the following modules (M).

M1.Release of one Trichocard *(Trichogramma* parasitised *Corcyra* egg cards) which was cut into 16 bits and stapled on the cotton plants randomly.

2. After 8- 10 days of release of the trichogrammatids, tricosane-treated dispensers (32 in numbers) along with the *Corcyra* egg card cut into 32 bits and placed on the 32 plants. Dispensers were kept at the proximity of egg bits.

3. The application was repeated after 8 to 10 days of first treatment imposition.

M2: As above but with septa impregranted with tricosane + pentacosane

Treated control (treatment 3):

M3: Treated control

1. Release of one Tricho card *(Trichogramma* parasitised *Corcyra* egg cards) which was cut into 16 bits and stapled on the cotton plants randomly.
2. After 8 to 10 days of first release one more Tricho card was cut into 16 bits and stapled on the cotton plants.

M4: Untreated control

A maximum recovery of 28.8% was recorded in M2 (Pentacosane+Tricosane-treated dispensers) which was significantly superior over M1 (Tricosane) and M3 (treated control) treatments. Untreated control recorded a minimum of 8.9 % recovery (Table 61). Minimum fruiting bodies damage of 12.9 % was recorded in Pentacosane+Tricosane-treated plot which was on par with Tricosane -treated plot and treated control plot but it was significantly superior to untreated control which recorded 17.6 % fruiting bodies damage. A maximum seed cotton yield of 1605 kg/ha was recorded in Pentacosane+Tricosane-treated plot which was on par with Module1. Untreated control recorded minimum seed cotton yield of 1395 kg/ha.

5.4 BIOLOGICAL SUPPRESSION OF TOBACCO PESTS

(i) Biological control of *Spodoptera exigua* in tobacco nurseries with biopesticides

CTRI

Nomuraea rileyi and *B. bassiana* both at 10^{13} spores/ha were as effective as neem seed kernel extract 2% in reducing damage to tobacco seedlings by *S. exigua* larvae. The EPN *Steinernema carpocapsae* @ 2 lakh IJ/ha was not as effective as the fungal pathogens.

DOR *Bt* @ 3 kg/ha was as effective as chlorpyriphos 0.05% spray in reducing the seedling damage to 8.8%. The seedling damage in control was 36.0%.

(ii) Validation of trap crop and border crop modules for the management of lepidopteran pests on tobacco

CTRI

Experiments were conducted in 5 locations in East Godavari district covering an area of 5 ha to evaluate trap crops castor DCS-9 for *S. litura* and *Tagetes* for *H. armigera*.

At 10 days interval 50 randomly-selected plants were observed for pest incidence/ damage and natural enemy incidence. Yield data was recorded.

The results of experiments from 2005-07 revealed that the percentage of plants damaged by *H. armigera* in tobacco sole crop was significantly higher than in tobacco associated with *Tagetes*. Except at 45 DAT, there was significant difference in damage between two seasons. Parasitisation by hymenoptera was significantly higher in tobacco

Table 62. Validation of *Tagetes* as trap crop (Pooled data 2005-2007)

Treatment	Plants damaged (%) (*H. armigera*)			Larval parasitisation (%)					
				Hymenoptera *			Diptera **		
	30 DAT								
	A	B	AB	A	B	AB	A	B	AB
Tobacco sole crop	13.2	17.7	15.420.0	5.3	4.5	3.35.6	16.1	12.6	13.212.0
Tobacco + *Tagetes*	16.8	12.4	11.013.4	8.0	8.8	7.310.3	14.9	18.5	19.017.8
CD (*P* = 0.05)	2.1	1.2	NS	NS	3.1	NS	NS	1.7	NS
CV %	14.0	8.8		9.9	15.5		17.9	11.0	
	45 DAT								
Tobacco sole crop	13.4	31.9	18.59.2	10.1	14.5	7.321.6	0.0	1.7	0.03.3
Tobacco +*Tagetes*	11.0	15.6	8.412.9	18.0	13.6	12.914.2	3.7	2.0	0.04.2
CD (*P* = 0.05)	NS	12.1	2.9	2.2	NS	2.9	NS	NS	NS
CV %	21.8	16.3		15.2	9.8		24.3	14.5	
	60 DAT								
Tobacco sole crop	7.6	40.0	9.718.3	12.0	10.4	10.310.5	10.4	10.4	8.212.6
Tobacco + *Tagetes*	12.0	19.6	5.76.9	12.3	14.0	13.714.1	13.3	13.3	12.614.0
CD (*P* = 0.05)	2.9	2.0	2.8	NS	1.3	NS	1.7	1.3	1.9
CV %	15.3	10.6	15.2	31.6	10.6		14.2	11.0	

A – Seasons B – Treatments AB – Seasons x Treatments

**Apanteles, Campoletes chlorideae* ** *Carcelia illota, Peribaea orbata.*

with *Tagetes* than in tobacco grown alone. Between the seasons significant difference in parasitisation was not observed except at 45 DAT. Parasitisation by diptera was higher in tobacco grown along with *Tagetes* as border crop except at 45 DAT. Between the seasons the differences in parasitisation were significant only late in the season i.e. at 60 DAT (Table 62).

It can be concluded that *Tagetes* improved the natural enemy component (parasitisation) and reduced the damage caused by *H.armigera* in tobacco.

Per cent plants damaged by *S.litura* were significantly higher in tobacco sole crop than in tobacco grown alone. Between the seasons the occurrence of damage was significantly different. Damage was higher in the second year. Seasons had no impact on parasitisation by hymenoptera and diptera while tobacco grown with castor as trap crop had significantly higher parasitisation (Table 63).

Yields were 1.8% more where tobacco was grown with trap crops than in tobacco sole crop fetching an extra income of Rs. 1710/ha.

Constraints in adoption

1. Seeds of single whorl variety of *Tagetes* was difficult to o*Bt*ain as it has no commercial value and farmers need to develop their own stock of seed material.
2. Farmers preferred to grow *Tagetes* in between tobacco than around the field to avoid hindrance to cultural operations.
3. Castor was heavily infested by semilooper *Achaea janata* at some locations and farmers pulled out castor fearing semilooper might damage tobacco.
4. Farmers preferred to grow castor along the bunds but not around the fields to avoid hindrance to cultural operations. Farmers preferred dwarf castor variety as trap crop in tobacco.

Table 64. Efficacy of *Ha*NPV adjuvant on *Helicoverpa armigera*

Treatment	Mean number of larvae/ plant		Leaves damaged (%)	Green leaf yield (kg/ha)	Cured leaf yield (kg/ha)
	3 days	7 days	14.0^{c}	17894^{c}	2343^{bc}
*Ha*NPV @ 1.5×10^{12} POB/ha + boric acid 0.025% + Teepol 0.1% + surf 0.1%	1.9^{c}	0.9^{c}			
HaNPV + tannic acid 0.025% + teepol 0.1% + surf 0.1%	2.0^{bc}	1.0^{bc}	14.5^{c}	17158^{c}	2229^{bc}
HaNPV + jaggery + teepol 0.1%	2.4^{b}	1.9^{b}	17.9^{b}	13624^{b}	1738^{b}
HaNPV + starch 0.1% + jaggery 0.1%	2.4^{bc}	1.1^{bc}	15.5^{bc}	14606^{b}	2229^{bc}
HaNPV + surf 0.1% + teepol 0.1%	2.1^{bc}	1.4^{bc}	17.7^{b}	14210^{b}	2122^{bc}
HaNPV alone	2.2^{bc}	1.6^{b}	14.8^{c}	13851^{b}	2097^{bc}
Control	3.6^{a}	3.0^{a}	20.5^{a}	9429^{a}	1322^{a}

Means followed by the same letter in a column are not significantly different (P=0.05)

The data revealed that *Bt* was ineffective against the pod borers of pigeonpea in reducing the pod damage though there was a reduction in the population of the different species of pod borers. NSKE 5% was as effective as endosulfan in controlling the pest and increasing the grain yield (Table 65).

ANGRAU

The field evaluation of DOR *Bt* was done during *Kharif* 2006-07 at ARS, Tandur. The data showed that DOR *Bt* did not give significant control of the pest. The yield differences between the different treatments as well as control were not statistically significant.

AAU(A)

(a) Laboratory studies

In laboratory tests DOR *Bt* @ 2g/l produced 60.1% mortality of *H. armigera* larvae and 65.1% mortality of *Lampides* sp. as well as *Exelastis atomosa*.

(b) Field experiment on BDN-2 pigeonpea

Results of two season trials (2005-06 and 2006-07) indicated that *Bt* was able to reduce the population of different species of borers as well as pod damage significantly and increase the yield of seeds. However, the net return was found to be highest in endosulfan followed by NSKE 5% (Table 66).

(ii) Evaluation of BIPM package on soybean

CTRI

The BIPM package consisting of release of *Telenomus remus* against *S. litura* @ 1 lakh parasitoids/ha as soon as the egg masses of *S. litura* are observed, one spray of *Sl* NPV @ 1.5 x 10^{12} PIB/ha along with 0.5% crude sugar as adjuvant and one spray of *Bt kurstaki* @ 2 kg/ha as soon as early instar larvae are seen was compared with farmer's practice of sprays of chemical insecticides.

There was a significant reduction of larval population of *S. litura* in BIPM after release of *T. remus* as well as after one spray of Sl NPV over FP wherein one spray of chlorpyriphos was applied. A application of *Btk* was ineffective against the leaf webber. Yield of soybean seeds in BIPM was higher than in chemical control plot and the benefit was Rs. 4120/ha.

NRCS

The trial was conducted during *kharif* on the farm of Shri Shyamalal Patidar at village Jamli,

Table 65. Field efficacy of DOR *Bt* against pigeon pea borer complex at Puthur village, Coimbatore

Treatment	Post treatment (No. larvae/plant)			Pod damage (%)	Grain yield (kg/ha)
	Helicoverpa armigera	*Maruca testulalis*	*Exelastis atomosa*		
DOR *Bt* 2kg/ha	5.6[b]	1.2[c]	0.2[a]	18.8[b]	431.2[b]
DOR *Bt* 1kg/ha	6.3[b]	0.5[b]	0.2[a]	21.1[b]	410.0[b]
NSKE 5%	2.6[a]	1.1[c]	1.0[b]	11.5[a]	525.0[a]
Endosulfan 0.07%	1.8[a]	0.2[a]	0.1[a]	13.1[a]	531.1[a]
Control	14.2[c]	4.5[d]	1.1[b]	19.2[b]	412.1[b]

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 66. Efficacy of *Bt* against the pod borers of pigeonpea at Anand

Treatments	Larvae/10 plants			% Pod damage	Seed Yield	Net return
	Lampides sp.	*Exelastis atomosa*	*H. armigera*	(kg/ha)	Rs/ha	(over control)
DOR *Bt* @ 2kg/ha	1.4[a]	2.5[ab]	1.5[b]	14.41[ab]	1229[ab]	1,122
DOR *Bt* @ 1kg/ha	1.2[a]	3.0[b]	1.7[c]	16.19[b]	1121[bc]	1,746
NSKE @ 5%	1.4[a]	3.4[b]	2.0[d]	19.30[b]	1207[ab]	7,008
Endosulfan @ 0.07%	0.8[a]	1.80[c]	1.1[a]	12.21[a]	1427[a]	11,928
Control	2.7[b]	5.5[c]	3.8[d]	22.54[c]	903[c]	-

Means followed by the same letter in a column are not significantly different (P=0.05)

Tehsil Mhow, Indore on Soybean variety *Samrat*.

Kharif 2006 started with good conditions for germination and crop establishment. The incidence of seedling insect-pests viz. blue beetle (*Cneorane* spp.), linseed caterpillar (*S. exigua*) and stem fly (*Melanagromyza sojae*) was negligible. As soon as the first generation of *S. litura* and also the egg masses were noticed (3[rd] week of August), 1[st] release of *T. remus* was made. In FP plots, Triazophos 40 EC was sprayed @ 0.8 l/ha. To supplement the effect of parasitoid, *Sl* NPV was sprayed in BIPM, which had marked effect on larval population (4.21arvae/m after 5 days of spray). In FP plots it increased to 13.71arvae/m in same duration.

By the end of 2nd week of September, second generation egg masses of *S. litura* were noticed along with incidence of green semiloopers' complex comprising of *Chrysodeixis acuta*, *Plusia orichalcea* and *Gesonia gemma* (13.2 larvae/m in BIPM & 13.9 in FP). Second release of *T. remus* was followed by spray of *Bt* (Dipel) @ 2 ml on the next day in BIPM plots for the control of green semiloopers. After 7 days of release of *T. remus*, the populations of *S. litura* in BIPM plots was only to 4.61arvae/m as against 13.91arvae/m in FP plots. On the other hand, after 7 days of spray of *Bt*, the population of green semiloopers in BIPM plots was also significantly reduced to 2.3 larvae/m as against 14.11arvae/m in FP plots (Table 67).

There was a significant difference between the yield realized from BIPM plots and FP plots. The BIPM plots yielded 23.45 q/ha, whereas only 18.85 q/ha could be harvested from FP plots. With the use of BIPM package, additional yield of 4.6q/ha i.e. 24.4% could be realized.

Table 67. Comparison of BIPM package and farmers' practice for incidence of defoliators in soybean and grain yield		
Insect incidence	BIPM	FP
S. litura (larvae/m) 7 days after 1st release of *T. remus*	8.9	6.8
S. litura (larvae/m) 5 days after Sl NPV spray	4.2	13.7*
S. litura (larvae/m) 7 days after 2nd release of *T. remus*	4.6	17.4 *
Green semiloopers (larvae/m) 1 day before *Bt* spray	13.2	13.9
Green semiloopers (larvae/m) 7 days after spray	2.3	14.1*
Grain yield (kg/ha)	2345	1885*

* Differences between BIPM and FP significant by 't' test

5.6 BIOLOGICAL SUPPRESSION OF RICE PESTS

(i) Evaluation of DOR *Bt* against leaf folder

The efficacy of the *Bt* formulation developed by Directoarate of Oilseeds Research (DOR *Bt*) was evaluated in multilocation trials for efficacy against the leaf folder and stem borer of rice.

KAU

Results of the experiment at Karimangalam on Jyothi rice indicted that two sprays of DOR *Bt* @ 1.5 kg/ha reduced the leaf folder damage but not stem borer. At a higher dose of 2.0 kg/ha, DOR *Bt* recorded the highest grain yield (Table 68).

AAU(J)

The experiment at Jorhat also showed that DOR *Bt* was effective in controlling the pests or rice including the stem borer. The *Bt* treatments recorded higher yield of grain than the chemical insecticide (Table 69).

PAU

Evaluation of DOR *Bt* against leaf folder and stem borer of rice was conducted at farmer's field at Samrala (Distt. Ludhiana). The data revealed that DOR *Bt* @ 2 kg/ha was significantly more effective than monocrotophos in reducing the damage by lef folder and stem borer. Highest grain yield of 5890 kg/ha was recoded in DOR *Bt* @ 2 kg/ha which however was on par with monocrotophos (Table 70).

Table 68. Efficacy of DOR-*Bt* against rice leaf folder and stem borer

Treatment	Leaf folder larvae/	Leaf folder damage (%) hill	Dead hearts (%)	Grain yield (kg/ha)
DOR *Bt* @2 kg/ha	0.1ᵃ	0.2ᵃ	6.1ᵇ	4788ᵃ
DOR *Bt* @ 1.5 kg/ha	0.1ᵃ	0.4ᵃ	5.4ᵇ	4250ᵃᵇ
Ekalux 0.05%	0.1ᵃ	0.2ᵃ	1.4ᵃ	4578ᵃᵇ
Control	0.5ᵇ	2.5ᶜ	6.7ᵇ	3863ᵇ

Means followed by the same letter in a column are not significantly different (*P*=0.05)

Table 69. Efficacy of DOR-*Bt* against rice leaf folder and stem borer

Treatment	Leaf folder	Caseworms/ 10 plants damage (%)	Dead hearts (%)	Grain yield (kg/ha)
DOR *Bt* @2 kg/ha	1.5ᵃ	2.0ᵃ	2.2ᵃ	3087.5ᵃ
DOR *Bt* @ 1.5 kg/ha	1.4ᵃ	3.0ᵇ	2.8ᵇ	2992.3ᵃ
Chlorpyriphos	1.7ᵃ	3.0ᵇ	2.8ᵇ	2847.8ᵇ
Control	6.0ᵇ	7.0ᶜ	9.0ᶜ	2381.5ᶜ

Means followed by the same letter in a column are not significantly different (*P*=0.05)

Table 70. Efficacy of DOR-*Bt* against rice leaf folder and stem borer of rice (cv. PR 116)

Treatment	Leaves folded (%)		Dead hearts (%)	White ears (%)	Grain yield (q/ha)
	45 DAT	60 DAT	60 DAT		
DOR-*Bt* @2.0 kg/ha	0.4^{a}	0.3^{a}	0.8^{a}	1.1^{a}	58.9^{a}
DOR-*Bt* @ 1.5 kg/ha	0.5^{ab}	0.5^{b}	1.5^{c}	1.9^{b}	57.5^{b}
DOR-*Bt* @ 1.0 kg/ha	0.6^{b}	0.5^{b}	2.6^{d}	2.1^{c}	56.1^{c}
Monocrotophos 36 SL	0.5^{a}	0.4^{ab}	1.3^{b}	1.3^{a}	58.8^{a}
Control	2.2^{c}	1.8^{c}	3.8^{e}	2.3^{c}	55.4^{d}

Means followed by the same letter in a column are not significantly different (P=0.05)

(ii) Validation of biointensive pest management practices in organic rice production

PAU

The experiment on validation of BIPM in organic rice production was carried out at PAU, Ludhiana on *Basmati* rice and coarse rice. In the organic farming, green manuring was done with *Dhaincha* (*Sesbania aculeata*); *T. chilonis* and *T. japonicum* were released 3 times each @1,00,000/ ha at weekly interval starting 30DAT; In the recommended practices nutritional requirement was met with inorganic recommended fertilizers and in the integrated practices, half of the nutritional requirement was met with inorganic fertilizers and other half with organic fertilizers, 3 releases of *T. chilonis* and *T. japonicum* each @1,00,000/ha were done at weekly interval starting 30DAT.

On rice (Table 71), the incidence of stem borer at 60 DAT was lower in organic practices (0.3%) as compared to integrated practices (0.4%) and recommended practices (0.5%). The per cent white ears in the integrated practices and organic practices were lower (0.4%) than recommended practices (0.6%). The yield was highest in integrated practices (71.0q/ha) as compared to organic practices (62.8q/ha) and recommended practices (58.0q/ha).

Table 71. Validation of bio-intensive pest management practices in organic rice in Punjab during 2006

Treatment	Dead hearts (%)	White ears (%)	Grain yield (kg/ha)
Organic practices	0.3	0.4	6280
Recommended practices	0.5	0.6	5800
Integrated practices	0.4	0.4	7100

Table 72. Validation of bio-intensive pest management practices in organic *Basmati* rice in Punjab during 2006

Treatment	Leaves folded (%)	Dead hearts (%)	White ears (%)	Grain yield (kg/ha)
Organic practices	0.2	0.7	0.8	2420
Recommended practices	0.6	1.2	1.4	2790
Integrated practices	0.3	1.1	1.2	3220

On *Basmati* rice (Table 72), the incidence of the leaf folder at 60 DAT was slightly lower in organic practices as compared to integrated practices and recommended practices. Whereas the incidence of stem borer at 60 DAT was lower in integrated practices than organic practices and recommended practices. The per cent white ears were lowest in organic practices followed by integrated practices and recommended practices. The yield in the integrated practices was higher (32.2q/ha) than in recommended practices and organic practices.

It can be concluded that releases of *T. chilonis* and *T. japonicum* 3 times @ 1,00,000 per ha 3 times at weekly interval reduced the incidence of leaf folder and stem borer in organic and *Basmati* rice.

Organic practices	Recommended practices	Integrated practices
Green manuring with daincha; 3 releases inorganic *T. chilonis* and *T. japonicum* each 1 lakh/ha 30 DAT, 2nd, 6 weeks after transplanting	Recommended dose of fertilizer, 1st after 3weeks and second after 6weeks transplanting	Fertilizers: ½ the recommended dose of inorganic fertilizer in 2 splits; 1st 3 weeks after transplanting + ½ of organic manure; 3 releases of *T. chilonis* and *T. japonicum* each 1 lakh/ ha 30 DAT

KAU

During *kharif* and *rabi* 2006-07, biointensive pest management package was demonstrated over an area of 0.5 ha of rice variety Jyothi. The package consisted of farm yard manure @ 5 t/h, seed treatment with *Pseudomonas* @ 8g / kg, bird perches @ 10 nos / h and four releases of *T. japonicum* against stem borer and leaf folder. The results showed that coccinellid and spider counts were significantly higher in organic farming in both seasons. There were no significant differences in the damage caused by the stem borer and leaf folder during the *kharif* season but organic package recorded significantly lower damage by these pests during *rabi*. There was no significant variation in grain yield in *rabi* season, but in *kharif* season grain yield was significantly higher in organic farming plot with higher net return (Table 73).

AAU(J)

Validation of biointensive pest management practices in organic rice production against sucking pest, leaf folder and rice stem borer was conducted in a farmer's field during *kharif* 2005 and 2006. In the experiment there were three treatments

T_1: **Organic package**

Use of moderately resistant variety (cv. Ranjit)

Use of *Pseudomonas* (8 g/kg of seed) as seed treatment

Application of FYM (5 t/ha)

Application of *B.bassiana* (10^{13} spores/ha)

Use of bird perches (10/ha)

Release of *T. japonicum* (1 lakh/ha/week)

Spray of *P. fluorescens* (as per university recommendation)

T_2: **Conventional package** (chemical control)

T_3: **Farmers practice**

The pooled data for *kharif* 2005 and 2006 revealed that the organic package was superior in reducing the damage caused by green leaf hopper, leaf folder and stem borer as compared to conventional package and farmers' practice. Organic package gave the highest grain yield (3368.1 kg/ha) as against 2527.9 kg/ha in the farmers field (Table 74). However, no significant difference of

Table 73. Impact of organic farming on the pests of rice (cv. Jyothi) in Thrissur

Parameter	*Kharif*		*Rabi*	
	Organic	Conventional	Organic	Conventional
Dead hearts (%)	4.2	5.3	3.5	6.5
Leaf folder incidence(%)	1.7	1.4	0.2	1.1
Coccinellids/ hill	0.3	0.05	0.5	0.1
Spiders/ hill	0.6	0.1	0.4	0.04
Grain yield (kg/ha)	3954.7*	3722.0	3640.0	3825.0

* Values significantly different from conventional package

Table 74. Validation of bio-intensive pest management package in rice (cv. Ranjit) in Assam			
Parameter	Package		
	Organic	Conventional	Farmer's
GLH/ hill	7.2[a]	6.6[a]	14.8[b]
Leaf folder damage (%)	2.6[a]	4.6[b]	6.9[c]
Dead hearts (%)	3.9[a]	6.3[b]	10.6[c]
Yield of grain (kg/ha)	3368.1[a]	2926.2[b]	2527.9[c]
Net return (Rs. /ha.)	20501.0	16689.0	-

Means followed by the same letter in a column are not significantly different (P=0.05)

yield was found between conventional package and organic package. The cost benefit analysis showed that organic package gave the highest net profit (1: 8.30) in comparison to the conventional package.

NCIPM

On farm trial to validate bio-intensive pest management practices in organic rice (HSB-16) locally known as Taraori Rice was carried out at Kaithal in farmers participatory mode. The experiment was laid out in 0.5 ha area in certified organic as well as in conventional fields. This rice is susceptible to yellow stem borer, leaf folder and foliar diseases except partial resistance to neck blast. Field preparation was carried out as per organic norms and the field was augmented with *Trichoderma*-treated farm yard manure @ 6T/ha. Seed soaking with 1% *P. fluorescens* was given to manage seed-borne diseases. As a preventive measure, seedling root dip treatment was also carried out with 2% *P. fluorescens* before transplantation. Leaf folder made its appearance from August end, hence *B. bassiana* was sprayed to confine the level of damage. The crop was sprayed with *P. fluorescens* @ 2kg/ha as a preventive measure to contain foliar diseases.

In case on conventional trial the field was prepared as per recommended practices of Haryana state. The crop was sprayed with chemical pesticides such as Cartap 4G @ 1 kg a.i./ha and chlorpyriphos 20 EC @ 2 ml/lit to contain the insect menace. Similarly, fungicides such as carbendazim and hexaconazole were sprayed to contain brown spot and bacterial leaf blight. Observations were carried out in 36, 37 and 38th standard meteorological weeks for assessing the effectiveness *B. bassiana* with the help of percentage incidence of leaf folder. The incidence of yellow stem borer was quite less during this period hence the same has not been analyzed. The data was transformed using angular transformation. Repeated measurement ANOVA analysis was carried out using "Proc Mixed" of SAS software. The analysis of data indicated that the differences in the incidence of leaf folder in the crop managed through biointensive practices was significantly lesser in biointensive package than in farmers package.

Soil analysis indicated that the field under biointensive trial contains 0.37% of organic carbon in comparison to 0.35% in farmers' practices trial. The final yield of bio-intensive trial (1318 kg/ha) was higher than farmers practice (1191 kg/ha) (Table 75). It is worthy to note that bio-intensive trial was carried out in certified organic fields which is in fifth year and has completed all the formalities of conversion as per international standard and being certified by Indian office of M/S Skal International.

Table 75. Validation of bio-intensive pest management package (BIPM) in organic rice in Kaithal				
Treatment	Leaf folder (%) at standard meteorological week			Grain yield (kg/ha)
	36	37	38	
BIPM	8.9	10.2	8.3	1318.0
Farmer's practice	32.4	19.3	18.2	1191.0

cum-Research Farm, Assam Agricultural University, Jorhat and also from Alengmora, Jorhat and reared in the laboratory in wooden cages covered with nylon net for the emergence of natural enemies. However, the field-collected mustard sawflies were completely free from the attack of natural enemies.

MPKV

To identify the natural enemies of mustard sawfly, eggs and larvae were collected at three days interval from mustard and radish fields and were reared in laboratory and were regularly observed for parasitoid occurrence. But during this period no parasitoids were observed.

(ii) Laboratory screening of mustard sawfly larvae for susceptibility to DOR-5 (*Bt*) and other commercial *Bt* products

AAU(J)

Probit analysis of dose-mortality response revealed that there were only minor differences in the toxicity of the different *Bt* products. DOR *Bt* recorded the lowest LC_{50} at 96 h post treatment (Table 78). By 144 h post treatment however, all the *Bt* products recorded 100% mortality.

Table 78. Probit analysis of dosage mortality response of mustard sawfly larvae to different formulations of *Bt* 96 h post treatment

Bt source	Chi^2	Slope	LC_{50}	Fiducial limits	
(n-2)	'b'		(g/l)	Upper	Lower
DOR *Bt*	10.06	1.1	0.84	1.20	0.22
Biolep	13.17	3.3	0.93	1.06	0.70
Dipel	19.47	1.89	0.91	1.13	0.66
Biobit	12.88	1.86	1.30	1.90	0.99

5.8. BIOLOGICAL SUPPRESSION OF MAIZE PESTS

(i) Control of cutworm *Agrotis ipsilon* on maize with EPN

SKUAS&T (Jammu) in collaboration with PDBC

Results of the field trial on the efficacy of EPN against the cut worm *A. ipsilon* on maize revealed that application of *H. indica* @ 2 billion/ha resulted in lowest population and damage by *A. ipsilon* and highest yield (Table 79).

5.9. BIOLOGICAL SUPPRESSION OF COCONUT PESTS

(i) Evaluation of *Trichogramma embryophagum*, *Goniozus nephantidis* & *Cardiastethus exiguus* against *Opisina arenosella*

KAU

Data from a field experiment conducted at Vatanapilly beach area in Thrissur district showed that release of the different parasitoids and predator effectively reduced the population of the black headed caterpillar. Sequential release of *C. exiguus* and *G. nephantidis* was as effective as the release of the individual agent (Table 80).

Release of *T. embryophagum* was not as effective as the other natural enemies.

(ii) Biological suppression of *Oryctes rhinoceros* with *Metarhizium anisopliae* in homestead garden in Kerala

KAU

The experiment was carried out in three locations in Thrissur district, Vellanikkara, Mannuthy and Nettissery. *Metarhizium anisopliae* mass cultured in glass bottles containing coconut water.

Table 79. Evaluation of EPN against cutworm *Agrotis ipsilon* on maize

Treatment	Dose	Larval population/10 plants	Damaged plants (%)	Yield (kg/ha)
S. carpocapsae	1 b/ha	2.75	8.2	1685
S. carpocapsae	2 b/ha	2.25	7.3	1755
H. indica	1 b/ha	2.00	6.2	1840
H. indica	2 b/ha	1.25	5.0	2000
Control	-	3.75	10.4	1560

Table 80. Efficacy of natural enemies against *Opisina arenosella*	
Treatment	Larvae/10 leaflets
T. embryophagum adults @ 1000/ palm	1.3
C. exiguus nymphs @ 50/palm	0.6
G. nephantidis adults @ 10/palm	0.6
Sequential release of *T. embryophagum* & *G. nephantidis*	0.3
Sequential release of *C. exiguus* & *G. nephantidis*	0.3
Untreated control	3.3

Twenty-five days after inoculation, the fungal mass was applied in manure pits @ 10 bottles / sq.m area. The fungus could kill all the larvae in the pits within three months in all three locations. Subsequently the incidence of the pest was reduced from 100% at the beginning of the experiment to 6.6% after three months.

(iii) Field evaluation of new formulations of *Hirsutella thompsonii* against coconut mite

PDBC

Results of a field trial laid out at Huskuru (Bangalore Rural district) on the efficacy for evaluating of *H. thompsoniii* (mycelial formulation) in combination with three selected adjuvants against the coconut mite, showed that three sprays of *H. thompsoniii* in combination with either glycerol, yeast extract powder or malt extract broth (MEB) significantly reduced the population of the coconut mite on the nut surface. The fungus was able to cause disease in the mite on all the sprayed trees as evidenced during the post-treatment sampling and reduced the population by about 90 %. Pre-harvest scoring of damage on the nuts indicated that *H. thompsonii* + glycerol 0.5% as an adjuvant was the most effective in reducing the injury caused by the mite (Table 81).

KAU

Results of the trial at Kerala also indicated that *H. thompsonii* along with adjuvants could reduce the population of the mites as effectively as the acaricide, dicofol. But pre-harvest scoring of nuts for damage did not show any significant effect of *H. thompsonii*.

(iv) Biological control of *O. arenosella* using *Bracon* spp.

CPCRI

Bracon species were collected from 7 locations namely, Kasaragod, Kollam (Cantt.). Kollam (Asramam), Trivandrum and Kottayam of Kerala, Aliyarnagar of Tamil Nadu and Pitappally of Orissa. These collections were maintained individually in the laboratory. The comparative efficiency of the collections was assessed with regard to longevity, fecundity, female progeny production and number of host larvae parasitised. The data indicated significant difference in these characters between the collections. Kasaragod and Pitappally (Orissa) collections were superior to others with regard to longevity, number of larvae parasitised and fecundity. Female progeny production was more in Trivandrum and Orissa cultures.

Table 81. Field evaluation of new formulations of *Hirsutella thompsonii* against *Aceria guerreronis*

Treatment	Live mites (no./mm^2)		Damage grade
	Pre-treatment	Post-treatment	
H. thompsonii (1%) + glycerol (0.5%)	5.22	0.84^a	1.96^a
H. thompsonii (1%) + yeast extract (0.5%)	7.19	1.61^a	2.13^a
H. thompsonii (1%)+ malt extract (0.5%)	8.27	0.31^a	2.16^a
Triazophos (Trifos 40) (0.2%)	6.43	0.71^a	1.98^a
Control	8.81	11.18^b	4.01^b

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 82. Efficacy of biocontrol components against *Oryctes rhinoceros*			
Treatment	Leaf damage (%)		Reduction in leaf damage (%)
	Pre-treatment	Post-treatment	
OBV+GMF+ pheromone trap	27.3	14.5	45.9
GMF+OBV	25.2	17.9	31.7
GMF trap	26.6	25.9	3.7
OBV release	18.0	10.5	44.4
Pheromone trap	31.5	30.8	15.5
Control	31.5	30.8	3.2

(v) Management of *Oryctes rhinoceros* through integration of green muscardine fungus (GMF), *Oryctes* baculovirus (OBV) and attractant-baited pheromone traps

CPCRI

The experiment was conducted at Krishnapuram with six treatments. Each plot consisted of an area of 1 acre in different blocks of CPCRI farm. Observations were recorded from 15 palms under each treatment. The percentage of leaf damage was recorded prior to initiation of treatment and also at 6 months interval (Table 82). There was 3.7 to 45% reduction in leaf damage in various treatments. Maximum percentage reduction in leaf damage (45.9%) was obtained in the plot where all the three components were imposed, viz. OBV+GMF+ Pheromone trap followed by OBV release plot (44.4%). There was an average collection of 216 beetles/trap/year in the pheromone trap.

5.10. BIOLOGICAL SUPPRESSION OF PESTS IN TROPICAL FRUITS

(i) Population dynamics of *Coccus viridis* and its natural enemies on sapota

IIHR

The population of green scales ranged from 11.8/leaf in July to 1.1/leaf in December 06 (Table 83). During the study period, the aphelinid parasitoid *Coccophagus* sp. and the two coccinellid predators *Chilocorus nigrita* and *Cryptolaemus montrouzieri* were observed. The parasitism by *Coccophagus* sp. ranged from 60.2% in April 2006 to 93.4% in October 2006. The predator *Chilocorus nigrita* was observed in negligible numbers in August to December 06 (Fig.15). The population of the scale was found to be very low mainly due to the activity of *Coccophagus* sp.

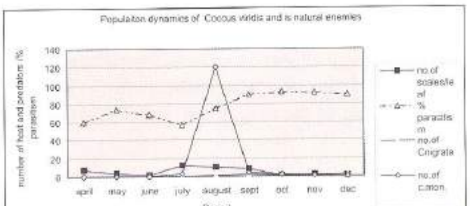

Fig. 15. Population of the soft green scale parasitised by *Coccophagus* sp. and other natural enemies

(ii) Effect of off-season release of *C. montrouzieri* on mealybugs on custard apple

IIHR

Release of *C. montrouzieri* @ 30 larvae/plant in off-season before fruit setting (about three months prior to harvesting of fruits) resulted in the reduction of 37.0% infestation on plant and 18.9% on fruits during fruiting season of October 2006.

(iii) Toxicity of newer pesticides to *C. montrouzieri*

IIHR

A total of eight new molecules were tested for their relative toxicity to the adults of *C. montrouzieri*. Both the initial toxicity on the day of application and residual toxicity at different days after application were studied. Among them, profenophos + cypermethrin and bifenthrin both at

1ml/l proved to be the most toxic to the adult beetles causing 80 –100% mortality on the day of application. Imidacloprid 0.5ml/l, abamectin 0.5ml/lit, fluvalinate 0.5ml/l, profenophos 1ml/l, ethofenprox 1ml/l, flufenoxuron 1ml/l did not cause any mortality of *C. montrouzieri* on the day of application. Residual toxicity studies indicated that profenophos + cypermethrin proved to be harmless on 7th day of application while bifenthrin proved to be safe only on 14th day of application to the adult beetles.

(iv) Evaluation of *Bt* formulations against the leaf miner on acid lime and pomello

IIHR

The effect of commercial formulations of *Bacillus thurinigiensis* var. *kurstaki* (*Btk*), viz. Dipel, and Halt were evaluated against *Phyllocnistic citrella* in Pomello. Totally, there were six treatments including unsprayed control: Dipel @ 0.5 and 1 ml/L, Halt @1ml/l followed by Neem soap @10g/l and Deltamethrin @ 2ml/l were evaluated. A total of six sprays were given at weekly interval. Insecticide was given at fortnightly interval.

A mean larval population of 0.9, 1.6 and 2.7 was recorded in *Bt* formulations (Dipel @1 and 0.5 ml/l, Halt @1ml/l) that was found to be at par to check (0.7 larvae/plant) and significantly less than control (5.5larvae/plant). Among the various *Bt* formulations, Dipel @ 1 ml was observed to record minimum leaf miner incidence

(v) Demonstration trial on the use of *C. montrouzieri* for controlling the pink mealybug *Maconellicoccus hirsutus* on grapes

NRCG in collaboration with PDBC & IIHR

Severe infestation of the pink mealybug *Maconellicoccus hirsutus* was observed in the grape orchard (cv. Thompson seedless) of 5 hectares at Tuljapur near Solapur in Maharashtra in March 2006. A mean of 70.5% of the bunches were found infested with the pink mealybug in spite of the application of 17 sprays of insecticides like dichlorvos, carbaryl, imidacloprid, methomyl, clothianidin, thiamethoxam, etc. The crop was pruned on 13 October 2006. Thrips and flea beetles were managed with the application of dochlorvos, imdacloprid and spinosad up to 60 days after pruning. Release of Australian ladybird beetle *C. montrouzieri* was initiated on 14 December 2006 and continued up to 10 February 2007. A total of 25000 larvae of *C. montrouzieri* were released @5000/ha during the above period.

Observations revealed that the predators effectively controlled the population of the mealy bugs and reduced the incidence to just 0.95% by March 2007.

5.11. BIOLOGICAL SUPPRESSION OF PESTS OF TEMPERATE FRUITS

(i) Development of bio-intensive IPM for San Jose Scale, *Quadraspidiotus perniciosus* in apple ecosystem

SKUAS&T

Analysis of data on parasitism of San Jose scale from samples of infested twigs, collected from different orchards, viz. IPM-managed orchard, Farmers' orchard and unmanaged orchard from March to September revealed varying pattern of parasitism. Average number of scales/ 2 sq.cm in IPM orchards was always much lower than in non-IPM orchards during all the periods of observations. Per cent parasitism however was found comparatively higher in IPM than in non-IPM plots.

The results indicated that usefulness of release of the parasitoid at more than 100/ tree for the management of the San Jose scale.

(ii) Field evaluation of *Trichogramma embryophagum* against the codling moth, *Cydia pomonella* on apple

SKUAS&T

Five Tricho cards/ tree, each containing 2000 eggs parasitised by *T. embryophagum* were used alone and in combination with mating disrupting pheromone (Disrupt CM Xtra) and chlorpyriphos (0.05%) during 3rd week of June 2006 both at Leh and Kargil, and data collected on infestation on fallen fruits as well as fruits on tree. Data revealed that *T. embryophagum* in combination with chlorpyriphos reduced the infestation of both fallen fruits and fruits on trees by 53.6 and 58.8%

followed by mating disrupting pheromone + *T. embryophagum* (49.0 and 53.0%). *T. embryophagum* alone could reduce the infestation only by 3 to 6% at both Leh and Kargil.

Future investigation will focus on timing, frequency, dosage and mode of release of *T. embryophagum* in order to evaluate its effectiveness against the codling moth.

(iii) Evaluation of fungal pathogens against the European red mite, *Panonychus ulmi*

SKUAS&T

Various fungal pathogens, viz. *V. lecanii, H. thompsonii, B. bassiana* and *M. anisopliae* each at concentration of 1x 10^9 spores/ml were evaluated for their efficacy against the European red mite, *Panonychus ulmi* under laboratory conditions in the division of Entomology, SKUAST-K. Leaf discs were made from fresh apple leaves and evaluation was carried out by leaf disc application (dipping) method.

The mortality data indicated that *V. lecanii* and *H. thompsonii* were the most effective recording a mortality of 43.3% on day nine and 53.3% on day 15 (Table 83).

(iv) Mass production of predatory mites

Dr.YSPUH&F

The culture of the predatory mite, *Amblyseius longispinosus* was maintained in winters on

Table 83. Relative susceptibility of *Panonychus ulmi* to fungal pathogens

Treatment	Mortality (%) (days after application)		
	3	9	15
V. lecanii	33.3	43.3^a	53.3^a
H. thompsonii	20.0	43.3^a	53.3^a
B. bassiana	13.3	23.3^b	36.6^b
M. anisopliae	33.3	30.0^b	36.6^b
Control	10.0	16.6^b	23.3^b

Means followed by the same letter in a column are not significantly different (P=0.05)

Tetranychus telarius grown on excised mite-infested rose leaves kept on wet sponge in Petri plates. It was found to be a good predator of the two spotted spider mite. It preferred nymphs and adults to eggs. At a minimum and maximum temperature range of 0.5-5.9°C and 18.4-22.7°C and relative humidity range of 20-91%, adults survived for 19.4 ± 12.9 (4 - 37) days. The predatory mite completed its development from egg to adult stage in 8.8 days. A single female laid 11.2 ± 4.9 (maximum 17) eggs in her life-time in winter with a survival of 4-37 (19.4 ± 12.9) days but hatchability was 100%. Thus it was possible to maintain the culture of these predatory mites in winter.

Recently, a predatory mite *Amblyseius* (*Euseius*) *delhiensis* has been collected and found feeding on *T. telarius* and the greenhouse whitefly nymphs, *Trialeurodes vaporariorum.*

(v) Evaluation of some microbial agents against apple root borer, *Dorysthenes hugelii*

Dr.YSPUH&F

First instar larvae of the apple root borer were found sensitive to RPN *S. feltiae* applied at 2X10^5 IJs/m^2. All larvae died in 10 days. Nematodes were found in the body of dead larvae. Recently, some mycosed grubs have been collected from the field and the fungus appears to be *Metarhizium anisopliae*.

(vi) Control of edaphic populations of the apple woolly aphid using EPN

Dr.YSPUH&F in collaboration with PDBC

The EPNs, *Heterorhabditis bacteriophora* (2.83 lakh IJs/tree) and *Steinernema feltiae* (2.9 lakh IJs/tree), supplied by PDBC, were applied around the trunk in the basin of the apple tree having infestation of the woolly apple aphid in the root zone in second week of August 2006. Before application of nematodes, soil was carefully removed around the tree trunk and number of aphid colonies was counted. It was 23 and 38 on these two trees. One month after application, again the colony count was taken. There was no reduction in the number of colonies in the root zone of treated trees and colonies were present on roots of the tree even in March 2007.

Table 87. Efficacy of DOR *Bt* on DBM of cabbage				
Treatment	Larvae/ plant	Larval parasitism (%)	Yield (kg/ha)	Net profit (Rs/ha)
DOR *Bt* @ 1 kg/ha	1.55[a]	28.7	15288[b]	89248.57
Endosulfan 0.05%	1.83[a]	5.09	17968[a]	106807.14
Control	2.82[b]	28.2	12693[c]	76157.14
Means followed by the same letter in a column are not significantly different (*P*=0.05)				

Table 88. Shoot and fruit borer infestation in brinjal			
Treatment	Infestation (%)		Fruit yield (kg/ha)
	Shoots	Fruits	
Bt 2kg/ha	2.0[ab]	13.6[a]	10638.1
EPN @1b/ha	2.2[b]	15.5[ab]	10046.0
EPN @2b/ha	2.1[b]	14.3[a]	10494.9
T. chilonis @ 50000/ha	1.4[ab]	17.9[b]	8637.5
Quinlaphos 0.05%	1.1[a]	16.4[ab]	10543.1
Control	5.5[c]	23.5[c]	90977.9
Means followed by the same letter in a column are not significantly different (*P*=0.05)			

IIHR, Bangalore to evaluate the efficacy of various microbial control agents in controlling DBM indicated that spraying *Bt* (Dipel) @ 1ml/l five times at weekly intervals recorded the lowest larval population followed by DOR *Bt* @ 1g/l (Table 86).

MPKV

The larval population of *Plutella xylostella* in crop treated with *Bt* and endosulfan was significantly lower when compared to control and remained low even after 15 days after spray. The highest yield however was recorded in the plots treated with endosulfan followed by *Bt*. Further, it is also clear that yield obtained in the crop treated with endosulfan was significantly higher than in *Bt* treated crop. The larval parasitism was 28.7% in *Bt* treated crops compared to 5.09% in endosulfan treated crops. The larval parasitism in control field was 28.2% which is almost at par with *Bt*-treated crop (Table 87).

(iii) Biological control of brinjal shoot and fruit borer

KAU

Results of two season experiments conducted during 2005-06 and 2006-07 indicated that four applications of *Bt* @ 2 kg/ha at 10 days interval and release of *T. chilonis* @ 50,000/ha recorded the lowest incidence of the shoot borer and this was on par with quinalphos 0.05% spray. *Bt* also recorded the lowest fruit damage which was on par with EPN @ 2 billion/ha as well as quinalphos. The differences in the yield of fruits however were not significant (Table 88).

Table 89. Evaluation of EPN against brinjal fruit borer		
Treatment	Fruit damage (%)	Fruit yield (kg/ha)
EPN @1billion/ha	17.4	8070[d]
EPN @2 billion/ha	16.4	10030[b]
T. chilonis @ 50,000 adults/ha	17.3	9070[c]
Triazophos @ 530 g a.i./ha	14.8	19060[a]
Control	24.5	8020[d]
Means followed by the same letter in a column are not significantly different (*P*=0.05)		

PAU

All the treatments showed lower fruit damage than control (24.5%) but the differences were not significant (Table 89). Among the biocontrol treatments, EPN @ 2 billion/ha recorded the highest yield followed by *T. chilonis* released @ 50,000/ha. Hostathion @ 1325ml/ha however was significantly the most effective recording the highest yield (Table 89).

(iv) Feeding potential of *Orius tantillus* on chilli thrips

IIHR

Orius tantillus fed upon 1-2, 2-6, and 4-11 larvae of thrips during first, second and third instar nymphal instars, respectively. Adults consumed 6-25 second instar larvae daily with a mean of 13.05 larvae. The predator survived for 7 – 22 days on *Scirtothrips dorsalis*.

(v) Microbial control of *Trialeurodes vaporariorum* using fungal pathogens

Dr.YSPUH&F

In the polyhouse, cucumber crop infested with the greenhouse whitefly was treated with conidial suspension of *B. bassiana*, *M. anisopliae*, *P. fumosoroseus* and *V. lecanii* at 10^8 conidia/ml and imidacloprid 0.00925% as a standard treatment. As compared with imidacloprid giving 67.1% kill of nymphs, the fungal preparations proved less effective. Among the fungal pathogens maximum kill of 39.3% was obtained with *P. fumosoroseus* which was on par with *M. anisopliae* and *V. lecanii*. However, *B. bassiana* proved to be ineffective.

(vi) Evaluation of DOR *Bt* against fruit borers of brinjal

KAU

Results of two season experiments revealed tht four sprays of DOR *Bt* @ 2 kg/ha was the most effective in controlling the fruit borer damage and increasing the fruit yield significantly over control (Table 90).

PAU

The experiment on evaluation of DOR *Bt* against fruit borer of Brinjal was conducted at Entomology Farm PAU, Ludhiana on variety Punjab Basmati in a plot of 50m^2. Four sprays of DOR-*Bt* were given at 10 days interval starting from 30 days after transplanting and it was compared with three sprays of triazophos @ 500 g a.i./ha at 15 days interval. It was found that fruit damage was minimum in chemical control (17.1%) and it was on a par with higher and medium doses of DOR- *Bt*. Fruit damage was maximum in control (27.4%) and it was on a par with lower dose (1.0 kg/ha) of DOR-*Bt* (22.4%) but was significantly higher than all other treatments. The highest marketable yield was obtained in chemical control (17,220 kg/ha) followed by higher dose of 2.0 kg/ha of *Bt* which was on par with *Bt* @ 1.5 kg/ha. (Table 91).

Table 91. Efficacy of DOR *Bt* against shoot and fruit borer of brinjal (PAU)

Treatment	Fruit damage (%)	Fruit yield (kg/ha)
DOR *Bt* 2 kg/ha	18.2^{ab}	15020^{b}
DOR *Bt* 1.5 kg/ha	21.8^{ab}	13660^{bc}
DOR *Bt* 1 kg/ha	22.4^{b}	12340^{cd}
Triazophos @ 500 g a.i./ha	17.1^{a}	17220^{a}
Control	27.4^{c}	11220^{d}

Means followed by the same letter in a column are not significantly different (P=0.05)

(vii) Evaluation of DOR *Bt* formulation against fruit borer on okra

PAU

Results of the experiment on evaluation of DOR *Bt* formulation against fruit borer, on okra (Punjab- 8 variety) at Entomology farm, PAU, Ludhiana revealed that the fruit damage was lowest in higher dose of DOR *Bt* (2.0kg/ha) and it was on par with medium dose (1.5 kg/ha) and chemical control.

The highest yield of 11270 kg/ha was recorded from plots of DOR-*Bt* (2.0 kg/ha), which was on

Table 90. Efficacy of DOR *Bt* against shoot and fruit borer of brinjal

Treatment	Shoot infestation (%)	Fruit infestation (%)	Fruit yield (kg/ha)
Bt 2 kg/ha	8.9^{a}	17.9^{a}	8347.6^{a}
Bt 1.5 kg/ha	6.6^{a}	24.3^{ab}	5871.8^{b}
Bt 1 kg/ha	9.6^{a}	30.6^{bc}	6052.3^{b}
Malathion 0.05%	7.1^{a}	23.6^{ab}	6163.0^{b}
Control	14.0^{b}	38.9^{c}	5483.1^{b}

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 92. Efficacy of DOR *Bt* against fruit borer of okra		
Treatment	Fruit damage (%)	Fruit yield (kg/ha)
DOR *Bt* (2.0 kg/ha)	24.0ª	11270ª
DOR *Bt* (1.5 kg/ha)	27.7ª	10520ª
DOR *Bt* (1.0 kg/ha)	37.7ᵇ	8170ᵇ
Endosulfan @ 300 g a.i./ha	26.4ª	11630ª
Control	41.5ᶜ	6130ᵇ

par with *Bt* @ 1.5 kg/ha but significantly higher than DOR-*Bt* (1.0 kg/ha) and control (Table 92). On the basis of pooled analysis of two years, it can be concluded that DOR-*Bt* @ 1.5 kg/ha can be recommended for the management of fruit borer in okra.

(x) Effectiveness of various microbial pesticides and a summer oil against *Pieris brassicae* (Lepidoptera: Pieridae) on kale / knol khol on cauliflower

YSPUH&F

A field experiment with *Bacillus thuringiensis* ssp. *kurstaki* (*Btk*) 1kg/ha, *B. bassiana* (10^{11} conidia/l), *Metarhizium anisopliae* (10^{11} conidia/l), EcoNeem Plus 0.2%, DC-Tron Plus 0.75% (summer spray oil), and dichlorvos 0.05% was laid out on cauliflower for suppression of cabbage butterfly larvae during March 2006.

Results indicate that after first spray, there was a definite reduction in larval population in insecticide-treated plots, as almost all larvae had died next day, but larvae hatched from some of the egg clusters had survived by 5-day observation. Similar trend was noticed after second spray. However, with biopesticides, reduction in larval population was evident in *B. bassiana* and *B. thuringiensis*-treated plots after 5 days of the first spray, though statistically non-significant. Significant differences were noticed in 10-day observation and low larval population of 25.3 and 43.3/plant was recorded in plots treated with *B. bassiana* and dichlorvos as against 136.3 larvae/plant in the control (Table 93). In plots treated with *B. bassiana*, *B. thuringiensis* and *M. anisopliae* as

Table 93. Efficacy of some biopesticides against *Pieris brassicae* larvae on cauliflower		
Treatment	Larvae/ plant 10-days after	
	I spray	II spray
Btk (1kg/ha)	113.7ᶜ	16.0
B. bassiana (10^{11}conidia/l)	25.3ª	5.7
M. anisopliae (10^{11}conidia/l)	97.7ᵇᶜ	20.0
EcoNeem Plus (2ml/l)	70.0ᵇᶜ	13.0
DC-Tron Plus (0.75%)	106.3ᵇᶜ	20.7
DDVP (0.05%)	43.3ᵃᵇ	43.3
Control (water)	136.3ᶜ	21.7

Means followed by the same letter in a column are not significantly different (P=0.05)

well as in the control plots, larval population remained significantly low in pretreatment count of the second spray. This indicated that natural enemy complex and abiotic factors adversely affected the larval population to a great extent. Following second treatment, there was overall reduction in the count (including control) over the respective pretreatment count in 7-day observation and it was 97.3, 89.9, 78.9 and 68.6% in plots treated with EcoNeem, dichlorvos, oil and *B. thuringiensis*, respectively, as against 52.4% in the control, but these differences were non-significant. Mean damage to foliage varied non-significantly from 36.7 to 48.3% in different treatments.

The presented results are not in accordance with the results obtained last year, when *Btk* and neem treatment were superior to other biocontrol treatments. From this experiment, it can be concluded that natural enemies and abiotic factors put a considerable check on survival of *P. brassicae*. *Btk* and EcoNeem Plus were effective against young larvae of the pest but older larvae were not satisfactorily controlled by the treatment.

(xi) Development of biocontrol-based IPM module against cabbage pests

SDAU

The following treatments wre tested in Department of Entomology, C. P. College of

Agriculture, S. D. Agricultural University, Sardarkrushinagar;

T_1 (IPM)

1. Use of sex pheromone traps @ 5/ ha each for *H. armigera*, *S. litura* and *P. xylostella*.
2. Mechanical collection of egg masses and first instar larval masses of *S. litura* and destruct them.
3. Six releases of *Trichogramma chilonis* @ 50,000/ha/week at initiation of eggs in the field.
4. Spray of NSKS 5%

T_2 (Chemical module)

Alternate spray with methyl oxy demeton (0.03%), quinalphos (0.05%) and endosulfan (0.07%)

T_3 Farmer's practice

T_4 Control

In the first spraying, the chemical module recorded the lowest larval population of *H. armigera*, i.e. 2.48 larvae/plant. But it was at par with T_1 and T_3 treatment. Untreated block had maximum larval population (6.48 larvae / plant). Same trend was also observed at second and third spraying. The chemical module also recorded significantly lowest larval population of *S. litura* (3.38 larvae / plant). It was significantly superior to all treatments. T1 (4.19 larvae / plant) and T3 (5.22 larvae /plant) were equally effective. Same trend was also observed at third spraying but in second spraying, results were non significant. T2 treatment had lowest larval population (3.17 larvae / plant). The IPM module was on par with chemical pesticides in reducing the larval population of *P. xylostella*

Among all the treatments, significantly lowest head damage and highest yield were recorded in chemical control. The IPM module was significantly inferior to chemical treatment (Table 94).

Table 94. Biocontrol based IPM of caterpillar pests of cabbage

Treatment	Head damage (%)	Yield (kg/ha)
IPM	35.7^c	24400^c
Chemical control	29.1^a	27600^a
Farmers' practice	32.2^b	25400^b
Control	41.1^d	16400^d

Means followed by the same letter in a column are not significantly different (P=0.05)

(xii) Evaluation of *Trichogramma brassicae* alone and in combination with *Bt* against lepidopteran pests of cole crops (cabbage/cauliflower)

The efficacy of *Trichogramma brassicae* against *P. xylostella* was compared with Bt as well as a chemical insecticide in field experiments. Following treatments were tested

1. *Trichogramma brassicae* @ 1.0 lakh/ week x 6 releases
2. *Bt* @ 1kg/ha (2 sprays)
3. *T. brassicae*@1.0 lakh/ ha & *Bt*@1kg/ha (3 releases & 1 spray)
4. Spinosad (2 sprays)
5. Untreated control.

MPKV

It is apparent from the Table 95 that all treatments significantly reduced the larval population over control. *Bt* @ 1kg/ha and spinosad were at par. The lowest curd damage was obtained with spinosad followed by *Bt* @ 1kg/ha. Highest yield was obtained with spinosad, which however was at par with *Bt* (Table 95).

SKUAS&T

The biocontrol treatments reduced the larval population as well as damage to leaves and curds. However, the chemical insecticide was more effective. Maximum yield was also obtained in the treatment with spinosad, followed by *Bt* (1 kg/ha) and *T. brassicae* (1 lakh/ha) (Table 96).

IIHR

A field trial was conducted with *T. brassicae* in September 2006 in cabbage F1 hybrid cv. Unnati for the control of the DBM. The egg parasitoid was released at weekly intervals for six weeks @ 40 – 60 thousand adults / week (equaling to a total of 300000 adults ha^{-1}) and compared with other four

Table 95. Evaluation of *Trichogramma brassicae* alone and in combination with *Bt* against *Plutella xylostella* in cabbage at MPKV

Treatment	Larvae/ plant	Curd damage (%)	Larval parasitism (%)	Yield (kg/ha)
Trichogramma brassicae @ 1.0 lakh/weed	1.2[a]	26.9[c]	21.7	1,5035[c]
DOR *Bt* @ 1 kg/ha	1.2[a]	22.5[b]	20.3	19,025[ab]
T. brassicae @ 1.0 lakh/ ha + *Bt* @ 1 kg/ha	1.2[a]	26.9[c]	20.9	1,7685[b]
Spinosad @ 250 ml/ha	1.1[a]	18.5[a]	7.3	2,0358[a]
Control	1.8[b]	29.3[d]	21.3	1,3485[d]

Means followed by the same letter in a column are not significantly different (P=0.05)

Table 96. Evaluation of *Trichogramma brassicae* alone and in combination with *Bt* against lepidopteran pests of cauliflower at SKUAS&T

Treatment	Larvae (no./plant)	Leaves infested (%)	No. of damaged curds/m^2	Egg parasitism (%)	Larval parasitism (%)	Yield (kg/ha)
Trichogramma brassicae @ 1.0 lakh/weed	1.4	21.3	1.18	36.0	9.3	24,000
Bt @ 1 kg/ha (2 sprays)	1.9	20.8	1.21	18.3	11.3	24,200
T. brassicae @ 1 lakh/ha + *Bt* 1 kg/ha (one spray)	1.4	19.0	1.20	22.6	10.8	23,300
Spinosad 75g a.i./ha (2 spray)	0.9	10.6	0.45	8.6	7.4	28,200
Control	3.5	32.3	3.00	10.5	12.8	14,600

treatments such as two sprays of *Bt* given at fortnight interval @ 1g/l alone, two sprays of *Bt* given at fortnight interval @ 1g /l + egg parasitoid (released in six weeks @ 40 –60 thousand adults / week, equaling to a total of 300000 adults ha^{-1}), two sprays of spinosad @ 0.75ml/l given at 21 days interval, and control. All the treatments were imposed 21 days after planting. The treatments were applied on exploded plot design. Samples were drawn at weekly interval from 10 randomly-selected plants for taking observation on the population of the DBM larvae and parasitised larvae or cocoons present. Data on both total and marketable yield were recorded to determine the effect of these treatments. ANOVA was used to analyze the data.

Bt + egg parasitoid and spinosad were on par recording a mean of 1.18 larvae / plant, which were significantly superior to *Bt* alone (1.34 larvae/ plant) or parasitoid alone (1.80 larvae / plant). Nevertheless, all the treatments were significantly superior to control, which recorded a mean of 3.26 larvae / plant. *Bt* + egg parasitoid also recorded the highest yield of 46640 kg/ha, which is significantly higher than the spinosad treatment (41310 kg/ha). Interestingly, the egg parasitoid release field recorded 39640 kg/ha as against *Bt* alone (33910 kg/ha). The above treatments were significantly superior to the control, which recorded a yield of 26440 kg/ha. A similar trend was observed with marketable yield. The effect of above treatments on population of the parasitoid *Cotesia plutellae* Kurdj revealed that the activity of the parasitoid was unaffected by the egg parasitoid release compared to other treatments. This may be one of the reasons why higher yield as observed in parasitoid release field compared to *Bt* sprayed field.

(xiii) White grub (*Brahmina coriacea*) control using fungi and entomopathogenic nematodes

YSPUH&F

(a) Pathogenicity of entomopathogenic nematodes (EPN) and fungi

Steinernema feltiae @ $2x10^9$ infective juveniles (IJs) produced 20% mortality of second instar grubs of *Brahmina coriacea* within a week of treatment, which howevere did not increase further even after two weeks of treatment. Surface application of *S. feltiae* at $4x10^9$ IJ/ha in cups containing white grubs resulted in at the most 50% mortality after two weeks of treatment. Surprisingly, in none of the dead grubs, presence of nematode could be ascertained. *Heterorhabditis bacteriophora* produced a mortality of 70% 4 weeks after treatment with a dose of 2 x 10^9 IJs.

Conidial suspensions of *Beauveria brongniartii* (local isolate) and *B. bassiana* (PDBC), and commercial formulation of *B. bassiana* (10^9 conidia/g) were applied to ice cream cups each containing one second instar grub of *B. coriacea*. Maximum mortality of 70 % was obtained with the local isolate of *B. brongniartii* after 4 weeks of treatment and out of these, 60% died due to mycosis only.

In the potato farm of Department of Agriculture located at Kheradhar, near Rajgarh, heavy attack of white grubs was noticed in September. When the crop was near harvest, 12 and 95 grubs/m^2 were sampled at two locations and out of these 8.2 and 12.6% were found dead due to mycosis. Apparently healthy grubs were collected from dug out spots and brought to laboratory. After 15 days of collection, these were again examined for any disease symptoms and 22.9% of them had died due to fungal infection. Healthy grubs were transferred individually to ice cream cups containing sterilized soil. From sponge supplied by PDBC (dated 30.06.2006), EPNs *S. feltiae*, were extracted (28.7% alive) and in nematode suspension of 390 IJs/ml, 15 grubs were given dip treatment for 5 seconds and put individually in ice cream cup. In another set, 10 larvae were first given 5-second dip and then placed individually in cup in the soil; then on soil surface, nematode suspension was applied @ 40 IJs/cm^2 area (4 billion/ha). Fifteen larvae were kept untreated.

Grub mortality data recorded after 7, 14 and 30 days of treatment indicated gradual increase in mortality and maximum kill was obtained a month after the treatment, which was 46.7% in the lot given dip treatment, 50% in the lot given dip + soil application, and even in the control 33.3% grubs were found dead. In these lots, mortality due to mycosis was 13.3, 40 and 26.7%, respectively. Earlier in August, when nematodes were applied at 4 billion/ha on soil surface, mortality obtained was 50%. It was surprising to note that in none of the dead grub, nematodes were present.

(b) Field evaluation of some fungal preparations and entomopathogenic nematodes against white grubs in potato crop

Attempt was made to culture the local isolate of *B. brongniartii* on well rotten FYM after autoclaving it, with the aim of making fungus-enriched FYM for field application. However, we failed to get good growth of the fungus.

In the last week of June, *B. bassiana* (PDBC) and *B. brongniartii* (local isolate) and in last week of July, *B. bassiana* (Daman), *Heterorhabditis bacteriophora* and *Steinernema feltiae* were applied in 4m x 3m plots (3 replicates/ treatment) at Shilaroo (Government Potato Farm) by drenching the standing crop. Fungi were applied at 10^{14} conidia/ha, while EPNs were applied at $2x10^9$ IJs/ha. By mid of September, when crop was harvested, white grub population/m row (5 spots in each plot) was recorded; in addition to it, per cent damage on harvested tubers was also recorded. The white grub population per metre in treated plots

Table 97. Effect of application of entomopathogenic fungi (10^{14}/ha) and nematodes ($2x10^9$/ha) on population of white grubs and damage to tubers		
Treatment	Grub population/m	Tuber damage (%)
B. brongniartii	2.2	12.7
B. bassiana (PDBC)	5.4	41.4
B. bassiana (Daman)	4.2	15.8
H. bacteriophora	2.7	7.6
S. feltiae	4.9	32.3
Control	7.3	36.4

was lesser (2.2-5.4/m row) than that in the control (7.3 grubs/m) but all these values did not differ significantly in statistical test. Minimum population was recorded in *B. brongniartii*-treated plots. Minimum tuber damage was recorded in *H. bacteriophora* (7.6%) and highest in *B. bassiana* indicating the ineffectiveness of the latter (Table 97).

5.13. BIOLOGICAL SUPPRESSION OF WEEDS

(i) Survey for the natural enemies of *Cyperus rotundus*

AAU(J)

The survey for the occurrence of natural enemies of *C. rotundus* was carried out at Jorhat, Golaghat and Nagaon district. During the year 2007 a lepidopteran borer was observed in the Experimental Farm, Dept. of Horticulture, Assam Agricultural University, Jorhat and at Bagori, Nagaon district, which is being identified.

PAU

Cyperus rotundus samples were collected from different areas at fortnight interval from July to October 2006. These were processed for isolation of fungi on potato dextrose agar under aseptic conditions. *Fusarium* spp. and *Aspergillus* spp. were isolated to the extent of 2-3% during the period.

NRCWS

Surveys were conducted during 2006 in Jabalpur for the collection of promising weed pathogens against *C. rotundus*. Two leaf spot diseases were observed in the month of August and one rust disease was observed from September 2006 to February 2007. Maximum damage in *C. rotundus* due to rust disease in nature was noticed in the months of September-October. Two fungi were isolated from leaf spot, one was identified as *Colletotrichum dematium* and another is yet to be identified. The pathogenicity was proved for both the leaf spot fungi.

The rust fungus was identified as a species of *Puccinia*. On artificial inoculation in pot cultured *C. rotundus* plants, fungus successfully produced disease symptoms of minute, brown coloured uredinia after 8 days of inoculation. Inoculation of rust significantly reduced the tiller number, fresh weight of tillers and roots, and number, fresh and dry weight of nuts (Table 98). This damage potential was recorded in the months which were less favourable to disease development and much more damage of *C. rotundus* is expected in favourable months, i.e. September-October when 100% damage was observed in natural conditions due to rust disease.

The following insect species were recorded on *C. rotundus*:

1. *Bactra venosana* (Tortricid moth)

Table 98. Biomass reduction in *Cyperus rotundus* due to rust inoculation under pot experiments	
Parameter	Reduction (%)
Tiller number	25.0
Fresh weight of shoot	32.0
Fresh weight of root	12.9
Number of nuts	18.6
Fresh weight of nuts	26.0
Dry weight of nuts	25.0

Table 99. Efficacy of *Metarhizium anisopliae* against *Holotrichia longipennis* on soybean		
Treatment	Plant mortality (%) after 80 DAS	Grain yield (kg/ha)
M. anisopliae spore dust @ 1 x 10^{14} conidia/ha	25.0	1110
Chlorpyriphos 20 EC 0.20 kg a.i./ha	27.3	1083
Chlorpyriphos 20 EC 0.40 kg a.i./ha	17.3	1610
Chlorpyriphos 20 EC 200 g.a.i./ha + *M. anisopliae* (5 x 10^{13} conidia/ha)	21.4	1333
M. anisopliae spore dust@ 5 x 10^{13} conidia/ha at sowing + one dose at 22 days after MBE	28.9	1055
Imidacloprid 200SL @ 0.048 kg. a.i/ha at sowing time	13.1	1805
Imidacloprid 200 SL @ 0.048 kg a.i./ha + M. anisopliae spore dust @ 5 x 10^{13} conidia/ha at sowing	11.7	1999
Untreated control	49.9	667

2. *Bactra minima* (Tortricid moth)
3. *Psalis* sp.
4. *Athesapeuta cyperi* (a weevil)
5. *Rhopalosiphum nymphacae* (Aphid)

None of the species was however found effective in controlling the weed in the field. *Bactra minima* infestation ranged from 10 to 19% during June to October. It was 19% in July and 15% in September 2006. After egg laying on the plant, larvae tunneled into the upper portion of shoot. About 10-12 days were required to kill the plants and 2-3 plants were infested before pupation on the basal part of the plant. It was observed that the insect was not able to kill the plant completely as after killing of main shoots, plants produced side shoots after 7-9 days. Adult longevity was recorded as 6-14 days. A female was able to produce 70 to 150 eggs during its life.

3.14. BIOLOGICAL SUPPRESSION OF WHITE GRUBS

(i) Biological control of white grub, *Holotrichia longipennis* with *M. anisopliae* in soybean (cv. VLS-21) during *Kharif* 2005-06

Results of the field experiments conducted at the Research Station, Gaja (Dist. Tehri Garhwal) on Soybean (Var. VLS-21) indicated that *M. anisopliae* spore dust (5 x 10^{13} conidia/ha) in combination with imidacloprid 200 SL @ 0.048 kg a.i./ha proved to be the most effective and significantly superior over other treatments by registering lowest plant damage (11.72%) and highest grain yield (19.99 q/ha) (Table 99). *Metarhizium anisopliae* spore dust applied alone at 1x10^{14} and 5x10^{13} conidia/ha was not found promising in controlling the white grubs.

(ii) Biological suppression of white grub, *H. longipennis* through *Beauveria bassiana* in soybean (cv. VLS-21) during *kharif* 2005

Spore dust of *Beauveria bassiana* @ 5 x 10^{13} spores/ha + imidacloprid 200 SL @ 0.0248 kg a.i./ha proved most effective by registering lowest plant damage (10.3% plant mortality) and highest grain yield (20.27 q/ha). *Beauveria bassiana* spore dust applied alone at both the doses, i.e. 1 x 10^{14} and 5 x 10^{13} conidia/ha was not found effective.

(iii) Studies on bioefficacy of a local strain of *Steinernema glaseri* against third instar grubs of *H. longipennis* under laboratory conditions

Laboratory experiments showed that *S. glaseri* could produce 90% mortality of third instar larvae of *H. longipennis* within seven days when applied at a dose of 1500 IJs/grub. Microscopic examination of the smears confirmed the presence of IJ in the cadavers.

3.15. BIOLOGICAL SUPPRESSION OF PESTS IN POLYHOUSES

(i) Evaluation of fungal pathogens against thrips on capsicum

MPKV

The experiment was conducted under polyhouse conditions in Hi-Tech Floriculture Project, College of Agriculture, Pune on capsicum (var. Bombay). The fungal pathogens tested were: *M. anisopliae* @ 10^{10} conidia / l ; *V. lecanii* @ 10^{10} conidia / l; *B. bassiana* @ 10^{10} conidia / l; *Hirsutella thompsonii* @ 10 g / l; insecticide check (Methyl demeton 0.05%) and untreated control.Among the fungal pathogens tested, *M. anisopliae* was comparatively more effective than others. However, *B. bassiana* and *H. thompsonii* were found equally effective in reducing thrip number and increasing the yield (Table 100).

Table 100. Efficacy of fungal pathogens against thrips on capsicum in polyhouses

Treatment	Thrips* /3 leaves	Yield (kg / replication)
M. anisopliae	30.0^b	865.3^b
V. lecanii	34.7^b	736.8^c
B. bassiana	35.5^b	862.1^b
H. thompsonii	37.4^b	836.3^b
Methyl demeton	4.6^a	951.5^a
Control	82.6^c	586.5^d

* 7th day post spray

Means followed by the same letter in a column are not significantly different (P=0.05)

(ii) Evaluation of fungal pathogens for the control of thrips on gerbera plants

KAU

Survey conducted in Vellanikkara area shows that the pests present in Polyhouses on Gerbera and Croton plants were aphids, mealy bugs, scales, mites and thrips. Gerbera plants were found severely affected by thrips (*Frankliniella* sp.). So the fungal pathogens were tried for the control of thrips on gerbera.

Table 101. Efficacy of some fungal pathogens against thrips on gerbera

Treatment	Thrips/ 7 days leaf after spray	
	I	II
Verticel	1.2^b	0.2^b
Verticillium lecanii	1.6^b	0.3^b
Hirsutella thompsonii	0.7^b	0.4^b
Metarhizium anisopliae	2.0^b	0.6^b
Beaveria bassiana	1.8^b	0.9^b
Imidacloprid 0.006%	1.1^b	0.6^b
Control	4.9^a	4.3^a

Means followed by the same letter in a column are not significantly different (P=0.05)

The data on the population of thrips recorded seven days after the two sprays indicated that all the fungal pathogens were equally effective in reducing the population of thrips and on par with the chemical insecticide (Table 101).

NCIPM

An experiment was conducted under polyhouse conditions at Ram Nagar (Uttaranchal) for the management of white fly in the polyhouse in the last week of November 2006.

Two sprays of *V. lecanii* supplied by PDBC for the control of whitefly in gerbera was done at the rate of $1x10^6$ CFU/ml. After first spray population of whitefly had gone down but again the population increased very fast. When second

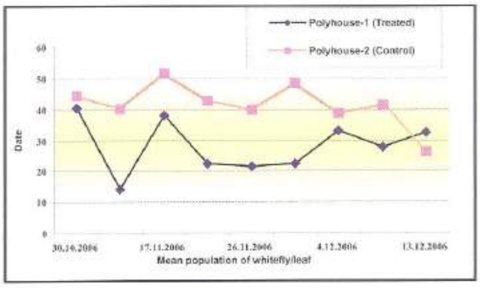

Fig. 16. Effect of application of *Verticillium lecanii* on whitefly infestation in gerbera

application of *V. lecanii* was done than the population was reduced considerably fast. However, four days later, the population increased again. These results indicate that under the experimental condition tested, weekly sprays of *V. lecanii* may be necessary (Fig. 16).

3.16. ESTABLISHMENT OF BIOCONTROL LABORATORY TO MASS PRODUCE SPECIFIED BIOCONTROL AGENTS

KAU

Established an insect pathology laboratory to produce *B. bassiana*, *M. anisopliae* and *V. lecanii*. This is to help in teaching and training of students, farmers and extension workers. *Metarhizium anisopliae* var. *major* was produced in bulk quantities for field level demonstrations on management of Rhinoceros beetle.

TNAU

Through lateral funding by government of Tamil Nadu and Coconut Development Board, large scale production and supply of the parasitoid, *Bracon hebetor* was taken up for the management of *O. arenosella* on coconut. Totally 2.88 million parasitoids were supplied to the Joint Director of Agriculture, Erode and the release was made in the project area, Arachalur, Modakurichi block, Erode district where 96,040 trees were brought under the biocontrol programme. The nucleus culture of parasitoids and predators are being supplied to The Department of Agriculture and post graduate research programme.

MPKV

During 2006-07, nucleus cultures of following laboratory host insects and natural enemies were maintained in the laboratory and supplied to other centres of AICRP on Biological Control for research purpose as well as use in field/ laboratory experiments at this centre.

Parasitoids : 1. *Copidosoma koehleri*
2. *Chelonus blackburni*
3. *Trichogramma chilonis*
4. *Trichogramma japonicum*
5. *Trichogramma pretiosum*
6. *Trichogrammatoidea bactrae*

Predators : 7. *Cryptolaemus montrouzieri*
8. *Dipha aphidivora*
9. *Micromus igorotus*

Microbial agents :10. NPV of *Helicoverpa armigera*
11. NPV of *Spodoptera litura*

Laboratory hosts :12. *Phthorimaea operculella*
13. *Corcyra cephalonica*
14. *Maconellicoccus hirsutus*
15. *Ceratovacuna lanigera*

Mass production of selected bioagents was also undertaken for experimental purpose, field demonstrations and supply to Biocontrol research units and farmers (Table 102).

CCSHAU

Biocontrol laboratories in CCSHAU, RRS, Karnal and Co-op. Sugar Mills of Sonipat, Jind, Mecham and Shabad mass produced biocontrol agents for use in sugarcane and sorghum.

VSI

During 2006-07, about 1049 lakh *T. chilonis* were produced with a monthly average of 87.45 lakhs. The production of *Chrysoperla carnea* was 75,212 eggs and 5,388 larvae. *Trichogramma* was supplied to 14 sugar factories and farmers for control of early shoot borer and internode borer in sugarcane on 272.80 ha area. During the period under report, 2,86,500 larvae and cocoons of *D. aphidivora* were collected and supplied. Further, during the rainy season, 26,000 *Micromus* larvae and cocoons were also supplied to the farmers through the sugar factories. Thus, in all 3,12,500 larvae and cocoons of the woolly aphid predators were supplied to farmers for the management of woolly aphid in the field.

Table 102. Production and sale of bioagents at MPKV

Bioagent	Quantity produced
T. chilonis	490 cards
C. koehleri	2,500 mummies
C. blackburni	700 adults
C. montrouzieri	4,500 beetles
M. igorotus	1,500 grubs
D. aphidivora	2,500 larvae
SlNPV	101

6. TECHNOLOGY ASSESSED, TRANSFERRED AND MATERIALS DEVELOPED

DNA sequences generated and deposited

Jalali, S. K., Ashok Kumar, G., Niranjana, P., Venkatesan, T., Murthy, K. S. and Lalitha, Y. 2006. Internal transcribed spacer-2 (ITS-2) sequence variation in *Trichogramma* species- *Trichogramma japonicum* internal transcribed spacer 2, complete sequence. Locus: 578 bp DNA. GenBank Accession No. DQ 471294.

Jalali, S. K., Ashok Kumar, G., Niranjana, P., Venkatesan, T., Murthy, K. S. and Lalitha, Y. 2006. Internal transcribed spacer-2 (ITS-2) sequence variation in *Trichogramma* species- *Trichogramma pretiosum* internal transcribed spacer 2, complete sequence. Locus: 517 bp DNA. GenBank Accession No. DQ 525178.

Jalali, S.K., Ashok Kumar, G., Niranjana, P., Venkatesan, T., Murthy, K. S. and Lalitha, Y. 2006. ITS-2 sequence variation in *Trichogramma japonicum* (bases 1- 578). Accession No. DQ 472294.

Venkatesan, T., Jalali, S.K., Ashok Kumar, G., Murthy, K. S. and Lalitha, Y. 2006. *Chrysoperla carnea* 5.8S ribosomal RNA gene, partial sequence; internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. GenBank Accession No. DQ825504.

Technology developed and transferred

Nagesh, M. - A simple design and technology for amorphous (talc) based formulations of antagonistic fungi.

CTRI, Rajahmundry – The use of trap crops mari gold and castor for the management of *Spodoptera litura* and *Helicoverpa armigera* respectively in tobacco has been assessed and validated in farmers fields during 2005-07.

GBPUA&T, Pantnagar – Mass multiplication method for *Pseudomonas fluorescens* on cow dung developed and validated and submitted for patenting.

KAU, Thrissur – The BIPM package for the management of rice leaf folder and stem borer by the release of *Trichogramma* spp. @ one lakh/ha has been validated in an area of 3000 acres in Adat Panchayath in Thrissur District. A video documentary on this technology was produced during 2006-07.

7. EDUCATION AND TRAINING

International

Name and designation	Training programme	Dates	Venue
Dr. R. J. Rabindra, Project Director and Dr. B.S. Bhumannavar, Principal Scientist	Seventh International Workshop on Biological Control and Management of *Chromolaena odorata* and *Mikania micrantha.*	12.9.2006 to 15.9.2006	National Pingtung University of Science and Technology, Pingtung, Taiwan
Dr. P. Sreerama Kumar, Senior Scientist	Twelfth International Congress of Acarology	21.8.2006 to 26.8.2006	University of Amsterdam, Amsterdam, The Netherlands
Dr. J. Poorani, Senior Scientist	Revisionary Studies on Coccinellids	25.10.2006 to 25.1.2007	Australian National Insect Collection (ANIC), CSIRO Entomology, Canberra, Australia
Ms. Ramandeep Kaur, Assistant Entomologist	International Course on Research and Development of New Concepts of Integrated Pest Management	8.5.2006 to 31.5.2006	Ministry of Agriculture and Rural Development, Volcani Campus, Bet Degan, Israel

National

Name and designation	Training programme	Dates	Venue
Dr. K. Srinivasa Murthy, Senior Scientist	National Workshop on Right to Information Act 2005	18.4.2006 to 19.4.2006	NAARM, Hyderabad
Dr. S. S. Hussaini, Principal Scientist	National Workshop on Right to Information Act 2005	28.4.2006 to 29.4.2006	The Capitol Hotel, Bangalore
Dr. P. L. Tandon, Principal Scientist	Programme on Domestic Enquiry and Disciplinary proceedings (NIAP)	19.5.2006 to 20.5.2006	The Capitol Hotel, Bangalore
Dr. (Ms.) Chandish R. Ballal, Senior Scientist	Strategies for Improving the Performanceof Farming Systems in Rainfed Areas	14.6.2006 to 15.6.2006	MANAGE, Hyderabad
Mr. Ajit Desai, Assistant and Ms. Nazia Anjum, Junior Clerk	Information Technology for the Finance Officers/ Officials of ICAR Institutes	13.6.2006 to 17.6.2006	NAARM, Hyderabad
Dr. Prashant Mohanraj, Senior Scientist	Special Workshop on the Contract Labour (Regulation & Abolition) Act,1970	28.6.2006 to 29.6.2006	Hotel Taj Residency, Bangalore

Mr. P. K. Sonkusare, Technical Officer	Maintenance of Personnel Management Information System Network (PERMIS net)	21.7.2006 to 22.7.2006	National Agricultural Science Complex, New Delhi
Dr. S. K. Jalali, Senior Scientist	Patenting in Biotechnology	19.10.2006 to 20.10.2006	National Research Development Corporation, New Delhi
Dr. N. Bakthavatsalam, Senior Scientist, Dr. P. Sreerama Kumar, Senior Scientist and Dr. S. Sriram, Scientist (SS)	National Seminar on Patenting in Biotechnology	26.10.2006	Hotel Taj Banjara, Hyderabad
Dr. N. Bakthavatsalam, Senior Scientist, Dr. P. Sreerama Kumar, Senior Scientist and Dr. S. Sriram, Scientist (SS)	Training on How to Draft a Specification and Prosecute Indian Patent Application	27.10.2006	Hotel Taj Banjara, Hyderabad
Dr. (Ms.) Y. Lalitha, Technical Officer	Training on Rearing, Production and Disease Management of Silkworm	13.11.2006 to 25.11.2006	CSR&TI, Mysore
Dr. K. Srinivasa Murthy, Senior Scientist	Trainers Development Programme on Right to Information Act 4	4.12.2006 to 8.12.2006	Institute of Secretariat Training and Management, Ministry of Personnel & Training, New Delhi
Dr. S. K. Jalali, Senior Scientist and Dr. T. Venkatesan, Senior Scientist	Molecular Characterization of Natural Enemies Using PCR Techniques	18.12.2006 to 23.12.2006	International Centre for Genetic Engineering and Biotechnology, New Delhi
Dr. K. Srinivasa Murthy, Senior Scientist	Hands on Training on Insect Cell Lines	25.1.2007 to 1.2.2007	International Centre for Genetic Engineering and Biotechnology, New Delhi
Dr. B. S. Bhumannavar, Principal Scientist	Project Formulation, Implementation and Evaluation	19.2.2007 to 02.3.2007	Administrative Staff College of India, Hyderabad
Dr. (Mrs.) Chandish R. Ballal, Senior Scientist	Stress management for Organisational Effectiveness	15.2.2007 to 21.2.2007	NAARM, Hyderabad
Dr. S. K. Jalali, Senior Scientist and Dr. B. Ramanujam, Senior Scientist	Techniques and Procedures for Measuring Impact Assessment	19.2.2007 to 20.2.2007	National Centre for Agriculture for Economic & Policy Research, New Delhi
Dr. (Ms.) Chandish R. Ballal, Senior Scientist and Dr. Sunil Joshi, Scientist (SS) Mr. P.K. Sonkusare, Technical Officer	Data Analysis with SPSS	2.3.2007	The Chancery Hotel, Bangalore
Dr. S. Ramani, Senior Scientist and Dr. Prashanth Mohan Raj, Senior Scientist	Taxonomy of Chalcid Parasitoids	14.3.2007 to 24.3.2007	Department of Zoology, Aligarh Muslim University, Aligarh

8. AWARDS AND RECOGNITIONS

PDBC, Bangalore

Dr. R. J. Rabindra

- Awarded the Certificate of Honour for contributions in the area of insect biocontrol during the Seventh Discussion Meeting in Entomology held at the Centre for Co-operation in Science and Technology among Developing Societies (CCSTDS), Chennai on 2 December 2006.
- Nominated as the ICAR representative to the Board of Management, University of Agricultural Sciences, Bangalore for the period 2006-09.
- Nominated as a Member, QRT, National Research Centre for Weed Science, Jabalpur.
- Nominated as a Member, RAC, NCIPM, New Delhi.
- Nominated as a Member, RAC, CITH, Srinagar.

Dr. N. S. Rao

- Nominated as a Member, QRT, National Research Centre for Onion and Garlic, Pune.

Dr. S. S. Hussaini

- Nominated as a Member, DBT Task Force on Biopesticides and IPM for 3 years.

Dr. B. S. Bhumannavar

- Received best research paper award for the research article titled, "Proboscis morphology and nature of fruit damage in different fruit piercing moths (Lepidoptera: Noctuidae) (Bhumannavar, B. S. and Viraktamath, C. A. 2001. Pest Management in Horticultural Ecosystem, 7(1): 28-40).

Dr. (Ms) Chandish R. Ballal

- Won the best paper award for the research paper entitled "Feeding preference of anthocorid predators for parasitised and un-parasitised eggs (Gupta, T. and Ballal, C. R.) at the National Symposium on Biological Control of Sucking Pests, Bangalore.
- Was admitted as a Fellow of Society for Biocontrol Advancement (FSBA), Bangalore in 2006.

Dr. S. Ramani

- Selected as a Member, RAC, Silkworm Seed Technology Laboratory (Central Silk Board), Kodathi, Bangalore for the year 2004-07.
- Selected as a Member, Research Advisory Committee (PG studies), Institute of Wood Science and Technology, Bangalore (FRI Deemed University Research Centre).

Dr. T. Venkatesan

- Admitted as a Fellow of Society for Biocontrol Advancement (FSBA), Bangalore in 2006.

Dr. P. Sreerama Kumar

- Won the second prize for the poster entitled "Screening for host-specificity of *Puccinia spegazzinii*: a potential biological control agent for *Mikania micrantha* (Usha Dev, Kumar, P. S., Ellison, C. A., Puzari, K. C., Sankaran, K. V., Nidhi Joshi, Khetarpal, R. K., Rabindra, R. J. and Murphy, S. T.) at the National Seminar on New Strides in Microbiology, Biochemistry, Biotechnology & Agriculture Sciences, Dehradun, 3-4 February 2007.
- Admitted as a Fellow of Society for Biocontrol Advancement (FSBA), Bangalore in May 2006.
- Admitted as a Fellow of Plant Protection Association of India (FPPAI), Hyderabad in March 2007.

- Awarded Partial Travel Support by the Department of Science and Technology, Government of India, for presenting an invited oral paper at the Twelfth International Congress of Acarology, University of Amsterdam, Amsterdam, The Netherlands, from 21-26 August 2006.

Dr. R. Rangeshwaran

- Received Ph.D. degree for his thesis titled "Comparative studies on the efficacy of endophytic and rhizospheric bacteria in plant growth promotion and biological control of soil borne fungal pathogens of chickpea" in Agricultural Microbiology by University of Agricultural Sciences, Bangalore.

Dr. M. Mani

- Won best oral paper award for the research paper entitled, "Field efficacy of Australian ladybird beetle, *Cryptolaemus montrouzieri* Mulsant in the suppression of striped mealybug, *Ferrisia virgata* (Cockrell) on tuberose" at the National Symposium on Biological Control of Sucking Pests, Bangalore.

Dr. A. Krishnamoorthy

- Awarded with Dr. S. Sithanantham Award for 2004-05 for his distinguished contribution in the field of biological control of insect pests of horticultural crops during the III National Symposium in horticulture: Emerging trends and challenges, 7-9 March 2007, Bangalore.

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

Research Projects – Lateral sources at Project Directorate of Biological Control, Bangalore

DBT

1. Development of biocontrol strategies for the management of sugarcane woolly aphid, *Ceratovacuna lanigera.*
2. Development of invert-emulsion formulation of *Trichoderma harzianum* and prolonged shelf-life and enhanced biocontrol potential.
3. Development of genetically improved strain of egg parasitoid *Trichogramma chilonis* with combined tolerance to insecticides and high temperature for the biological suppression of lepidopterous pests.
4. Isolation, purification and characterization of novel insecticidaltoxins from *Photorhabdus* and *Xenorhabdus* spp. of bacteria from entomopathogenic nematodes.
5. Evaluation of arbuscular mycorrhizal fungi and entomopathogenic nematode cruisers. interaction on the reproduction and development of rootknot nematode, *Meloidogyne incognita.*
6. Management of cardamom root grub, *Basilepta fulvicorne* with entomogenous nematodes.

ICAR Cess-Fund

1. Network project of biosystematics.
2. Development of a strain of *Trichogramma chilonis* tolerant to newer insecticides and high temperature.
3. Development of commercial formulations of antagonistic fungi (*Paecilomyces lilacinus* and *Verticillium chlamydosporium*) for biological control of *Meloidogyne incognita* and *Rotylenchulus reniformis.*

AMAAS (ICAR)

1. Development of a mycoherbicide-based biological control strategy for *Cyperus rotundus.*
2. Microbial control of insect pests – II.

DAC

1. Technology Mission for cotton.

DFID (UK)

1. Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii*: implementation phase.

10. AICRP / CO-ORDINATION UNIT / NATIONAL CENTRES

With a view to fulfill the mandate under PDBC and AICRP on BC effectively and efficiently, the Project Directorate is functioning with the following ICAR Institute-based and State Agricultural University-based centres.

Headquarters

Project Directorate of Biological Control, Bangalore	Basic research
ICAR Institute-based centers	
Regional Station, Central Plantation Crops Research Institute, Kayangulam	Coconut
Central Tobacco Research Institute, Rajahmundry	Tobacco, soybean
Indian Agricultural Research Institute, New Delhi	Basic research
Indian Institute of Horticultural Research, Bangalore	Fruits and 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 & Technology, Pantnagar	Plant disease antagonists
Gujarat Agricultural University, Anand	Cotton, pulses, oilseeds, vegetables and 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

Voluntary centres

National Research Centre for Soybean, Indore	Soybean
National Research Centre for Weed Science, Jabalpur	Weeds
Chaudhary Charan Singh Haryana Agricultural University, Hisar	Sugarcane
University of Agricultural Sciences, Bangalore	Cotton, pigeonpea
University of Agricultural Sciences, Dharwad	Cotton, chickpea
Vasantdada Sugar Institute, Pune	Sugarcane

11. LIST OF PUBLICATIONS

Research papers published in refereed scientific journals

(a) PDBC, Bangalore

Ali Mehrvar, Rabindra, R. J., Veenakumari, K. and Narabenchi, G. B. 2006. Comparative evaluation of yield productivity parameters of seven geographic isolates of nucleopolyhedrovirus of *Helicoverpa armigera* (Hubner) Lepidoptera: Nocutuidae). *Insect Environment*, **12**: 14-15.

Bajpai, N. K., Ballal, C. R., Rao, N. S., Singh, S. P. and Bhaskaran, T. V. 2006. Competitive Interaction between two ichneumonid parasitoids of *Spodoptera litura*. *Biocontrol*, 51: 419-438.

Bakthavatsalam, N. and Tandon, P. L. 2006. Kairomones, their optimum concentrations, and application techniques to enhance the parasitisation efficiency of *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae). *Journal of Biological Control*, **20**: 169-174.

Bakthavatsalam, N. and Tandon, P. L. 2006. Influence of strain variation and kairomonal compounds on the parasitising efficiency of *Trichogramma chilonis*. *Journal of Biological Control*, **20**: 13-18.

Ballal, C. R. and Singh, S. P. 2006. Effect of two host plants of *Helicoverpa armigera* (Hubner) on the feeding potential of three chrysopid predators – *Chrysoperla carnea* (Stephens), *Mallada boninensis* (Okomoto) and *Mallada astur* (Banks). *Entomon*, **31**: 113-119.

Ballal, C. R., Lyla, K. R., Joshi, S. and Lakshmi, L. 2006. Appropriate packaging for transportation of *Telenomus remus* Nixon (Hymenoptera: Scelionidae) egg cards. *Journal of Biological Control*, **20**: 219-224.

Gupta, T. and Ballal, C. R. 2006. Biology and feeding potential of an anthocorid predator, *Orius tantillus* (Heteroptera: Anthocoridae) on *Sitotroga cerealella*. *Indian Journal of Plant Protection*, **34**: 168-172.

Hariprasad, L. U. and Venkatesan, T. 2006. Effect of adult nutrition on the parasitisation, fecundity and longevity of *Goniozus nephantidis* (Muesebeck), an important Parasitoid of coconut black-headed caterpillar. *Annals of Plant Protection Sciences*, **14**: 502-503.

Jalali, S. K., Singh, S. P., Venkatesan, T., Murthy, K. S. and Lalitha, Y. 2006. Development of endosulfan tolerant strain of an egg parasitoid *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae). *Indian Journal of Experimental Biology*, **44**: 584-590.

Jalali, S. K., Murthy, K. S., Venkatesan, T., Lalitha, Y. and Devi, P. S. 2006. Adaptive performance of *Trichogramma chilonis* Ishii at low temperature. *Annals of Plant Protection Sciences*, **14**: 5- 7.

Jalali, S. K., Venkatesan, T., Murthy, K. S., Biswas, S. R. and Lalitha, Y. 2005. Influence of temperature and host density on functional response of *Telenomus remus* Nixon, an egg parasitoid of *Spodoptera litura* Fabricius. *Entomon*, **30**: 193-199.

Jalali, S. K., Venkatesan, T., Murthy, K. S., Rabindra, R. J., Lalitha, Y., Udikeri, S. S., Bheemanna, M., Sreenivas, A. G., Balagurunathan, R. and Yadav, D. N. 2006. Field efficacy of multiple insecticides tolerant strain of *Trichogramma chilonis* Ishii against American bollworm, *Helicoverpa armigera* (Hübner) on cotton. *Indian Journal of Plant Protection*, **34**: 173-180.

Mamatha G.S., D'Souza P.E., Nagesh M. and Chandrashekar S.C. 2005. Evaluation of nematode-trapping efficiency of *Arthrobotrys oligospora* against larvae of *Bunostomum* species. *Journal of Veterinary Parasitology*, **19**: 25-31.

Murthy, K. S., Jalali, S. K. and Venkatesan, T. 2006. Development of *Spodoptera exigua* Hubner (Lepidoptera: Noctuidae) on a semi-synthetic diet. *Indian Journal of Plant Protection*, **34**: 250-251.

Nagesh, M. Hussaini, S. S., Chidanandaswamy, B. S. and Biswas, S. R. 2006. Studies on simple mass production systems of nematophagous fungus, *Arthrobotrys oligospora* Fresinius. *International Journal of Nematology*, **16**: 28-35.

Nagesh, M., Hussaini, S.S., Ramanujam, B. and Chidanandaswamy, B. S. 2006. Management of *Meloidogyne incognita* and *Fusarium oxysporum lycoprsicae* wilt complex using antagonistic fungi in tomato. *Nematologia Mediterranea*. **34**: 63-68.

Navatha, S. and Srinivasa Murthy, K. 2006. Host preference for oviposition and feeding by Diamond back moth, *Plutella xylostella* Linn. *Annals of Plant Protection Sciences*, **14**: 283-286.

Nirmala, R., Ramanujam, B., Rabindra, R. J. and Rao, N. S. 2006. Effect of entomofungal pathogens on the mortality of three aphid species. *Journal of Biological Control*, **20**: 89-94.

Parray, M. A., Rangrez, M. A. and Tandon, P. L. 2006. Influence of egg number and size variability in *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae) within the card on parasitization efficiency and adult emergence of *Trichogramma chilonis* Ishii. *Journal of Eco-friendly Agriculture*, **1**: 80-81.

Poorani, J. and Booth, R.G. 2006. A new sibling species of *Halyzia straminea* (Hope) (Coleoptera: Coccinellidae: Coccinellinae) from the Indian subcontinent. *Zootaxa*, **1354**: 63–68.

Prathapan, K.D., Priyadarsanan, D., Narendran, T. C., Viraktamath, C. A., Subramanian, K. A., Aravind, N. A. and Poorani, J. 2006. Biological Diversity Act, 2002: Shadow of permit-raj over research. *Current Science*, **91**: 1006-7.

Puri, S.N., Sharma, O.P., Lavekar, R.C., Murthy, K.S. and Dhandapani, A. 2006. On-farm validation of Bio-intensive IPM module in rain-fed Cotton in Southern Maharashtra. *Indian Journal of Plant Protection*, **34**: 250-251.

Sankaranarayanan, C., Hussaini, S. S., Kumar, P. S. and Rangeshwaran, R. 2001. Biological control of reniform nematode, *Rotylenchulus reniformis* with nematophagous fungus *Verticillium chlamydosporium* Goddard on sunflower. *International Journal of Tropical Plant Diseases*, **19**: 1-6.

Sankaranarayanan, C., Hussaini, S. S., Rangeshwaran, R. and Kumar, P. S. 2001. Efficacy of *Pseudomonas fluorescens* alone and in combination with *Pasteuria penetrans* against plant parasitic nematodes. *International Journal of Tropical Plant Diseases*, **19**: 7-13.

Shakeela,V and Hussaini, S. S. 2006. Susceptibility of tobacco cutworm, *Spodoptera litura* Fabricius to some indigenous isolates of entomopathogenic nematodes. *Journal of Ecofriendly Agriculture*, **1**: 64-67.

Srinivasa Murthy, K., Jalali, S. K. and Venkatesan, T. 2006. Development of *Spodoptera exigua* (lepidoptera: Noctuidae) on a semi-synthetic diet. *Indian Journal of Plant Protection*, **34**: 248-249.

Veenakumari, K. and Prashanth Mohanraj. 2006. New report of *Myllocerus viridanus* Fabricius (Coleoptera: Curculionidae) on geranium (*Pelargonium* spp.). *Insect Environment*, **12**: 61-62.

Veenakumari, K., Rabindra, R. J., Srinivas Naik, C. D. and Shubha, M. R. 2006. First report of *Beauveria bassiana* (Balsamo) Vuillemin on *Amsacta albistriga* (Lepidoptera: Arctiidae) from, Karnataka, India. *Journal of Biological Control*, **20**: 95-96.

Veenakumari, K., Rabindra, R. J., Srinivas Naik, C. D. and Shubha, M. R. 2006. Standardization of laboratory mass production of *Amsacta albistriga* nucleopolyhedrovirus. *Journal of Biological Control*, **20**: 183-190.

Venkatesan, T., Jalali, S. K., Srinivasa Murthy, K. and Bhaskaran, T. V. 2006. Rearing of *Cheilomenes sexmaculata* on artificial diet and its predatory efficiency against *Aphis craccivora*. *Annals of Plant Protection Sciences*, **14**: 277-279.

Venkatesan, T., Jalali, S. K., Srinivasa Murthy. K., Rabindra, R. J. and Rao, N. S. 2006. Field evaluation of different doses of *Goniozus nephantidis* (Muesebeck) for the suppression of *Opisina arenosella* Walker on coconut. *International Journal on Coconut* R&D (CORD), **22** (special issue): 78-84.

Vidya, H. S. and Nagesh, M. 2006. RAPD analysis of Indian isolates of *Xenorhabdus* spp. associated with entomopathogenic nematodes, *Steinernema* spp. *International Journal of Nematology*, **16**:178-185.

(b) IIHR, Bangalore

Ganga Visalakshy, P. N., Krishnamoorthy, A. and Manoj Kumar, A. 2007. Compatibility between the plant antagonists *Trichoderma harzianum* Rifai, *T. viride* Pers.:Fr. and potential entomopathogenic fungi of horticultural crop pest. *Entomon*, **31**: 129-132.

Ranghanath, H. R., Ganga Visalakshy, P. N. and Krishna Kumar, N. K. 2006. An artificial diet for mass multiplication of the gherkin fruit borer, *Dipahain indica* (Saunders) (Lep: Pyralidae). *Pest Management in Horticultural Ecosystem*, **12**: 37-40.

(c) IISR, Lucknow

Baitha, A. and Srivastava, D.C. 2005. Field parasitisation of egg masses (II brood) of top borer, *Scirpophaga excerptalis* Walker. *Egg Parasitoid News*, **17**: 19.

Srivastava, Sangeeta, Singh, V., Gupta, Prasant, S., Sinha, O. K. and Baitha, A. 2006. Nested-PCR assay for detection of sugarcane grassy shoot phytoplasma in leafhopper vector *Deltocephalus vulgaris* Dash & Viraktamath: A first report. *Plant Pathology*, **55**: 25-28.

(d) SBI, Coimbatore

Mukunthan, N., Nirmala, R., Santhalakshmi, G., Srikanth, J. and Singaravelu, B. 2006. A simple mass rearing method for *Dipha aphidivora*, the pyralid predator of sugarcane woolly aphid, *Ceratovacuna lanigera*. *Sugar Tech* **8**: 160-165.

Srikanth, J., Santhalakshmi, G. and Tamizharasi, V. 2006. Viability and virulence of selected *Beauveria brongniartii* formulations against *Holotrichia serrata*. *Sugar Tech* **8**: 150-152.

(e) AAU, Jorhat

Bhattacharyya, B., Basit, A. and Saikia, D. K. 2006. Parasitoid and predators of rice insect pests of Jorhat district of Assam. *Journal of Biological Control*, **20**: 37-44.

Sarmah, S., Saikia, D. K. and Nath, R. 2006. Incidence of sugarcane wooly aphid *Ceratovacuna lanigera* Zhut (Homoptera: Aphididae) and its different natural enemies in Assam. *Insect Environment*, **12**: 82-83.

(f) ANGRAU, Hyderabad

Saritha, P. and Rahman, S. J. 2006. Optimization studies on incubation period and inoculum dosage for harvest of *Spodoptera litura* Fabricius NPV. *Journal of Life Sciences*, **21**: 2006.

(g) AAU, Anand

Bharpoda, T. M., Koshiya, D. J. and Korat, D. M. 2006. Survey of insect pests and their natural enemies on aonla. *Insect Environment*, **12**: 93-94.

(h) GBPUA&T, Pantnagar

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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. Biosystematics of *Trichogrammatids*
3. Introduction and studies on exotic natural enemies of some important crop pests and weeds
4. Interactions within the natural enemy guilds of *Ceratovacuna lanigera* and *Maconellicoccus hirsutus*
5. Rearing and evaluation of natural enemies with special reference to scelionid, braconid, ichneumonid and anthocorid groups
6. Development of novel mass production, storage and packing techniques for *Cryptolaemus montrouzieri*
7. Mass production and evaluation of *Micromus* sp.
8. Herbivore induced plant synomones and their utilization in enhancement of the efficiency of natural enemies
9. Host derived kairomones to enhance the efficiency of natural enemies
10. Development and evaluation of improved strains of trichogrammatids, *Cheilomenes sexmaculata* and *Chrysoperla carnea* tolerant to insecticides, temperature and high host searching ability
11. Selection of superior strain of predators, viz. *Chrysoperla carnea* (Stephens) and *Cryptolaemus montrouzieri* (Mulsant) from different agro-ecosystems and their molecular characterization
12. Selection of Superior strains of certain parasitoids and their characterization
13. *In vitro* cloning of NPV for genetic improvement
14. Development of improved formulations of NPV for management of *Helicoverpa armigera* and *Spodoptera litura* in tomato
15. Identification of pathogens of phytophagous mites and assessment of their potential in microbial control
16. Identification of *Trichoderma* isolates with enhanced biocontrol potential
17. Efficient formulations of *Trichoderma* sp. and entomofungal pathogens with prolonged shelf-life
18. Isolation, characterization and toxicity testing of indigenous *Bacillus thuringiensis* strains against lepidopterous pests
19. Isolation and characterization of plant growth promoting endophytic bacteria and development of improved formulations
20. Mass production, formulation and field-testing of entomopathogenic nematodes against important lepidopteran pests
21. Biological suppression of plant parasitic nematodes exploiting antagonistic fungi and bacteria in specific cropping systems
22. Database on entomopathogenic nematodes

Applied research

I. BIOLOGICAL CONTROL OF PLANT DISEASES AND NEMATODES USING ANTAGONISTIC ORGANISMS

1. Testing of bioefficacy of oil based and talc based formulations of biocontrol agents against foliar diseases (GBPUA&T, PAU, AAU(A), AAU(J))
2. *In vivo* compatibility between entomopathogens and fungal and bacterial antagonists (GBPUA&T)

3. Relative efficacy of mycoparastic and systemic resistance inducing strains of *Trichoderma* against soil borne and foliar diseases when applied through seed and soil (GBPUA&T)
4. Large-scale field-demonstration of *Trichoderma* at farmers' field (GBPUA&T)
5. Shelf-life of *Trichoderma* and *Pseudomonas* formulations (GBPUA&T and PDBC)
6. Biological control of pigeonpea cyst nematodes and disease complex (AAU (A) and TNAU*)
7. Biological control of post-harvest fruit rot in mango, guava and papaya using yeasts (PDBC, AAU (A) and GBPUA&T)
8. To evaluate the potential of selected agents in the management of fruit rot in mango/ papaya/ guava (PDBC & GBPUA&T)
9. Standardisation of method for genetic transformation of *Trichoderma harzianum* using gene gun (GBPUA&T)
10. Standardisation of method for genetic transformation of *Pseudomonas fluorescens* using gene gun (GBPUA&T)

II. BIOLOGICAL SUPPRESSION OF SUGARCANE PESTS

1. Bio-intensive pest management practices for sugarcane scales (CCSHAU and IISR)
2. Maintenance and supply of *Epiricania melanoleuca* for the biological control of *Pyrilla perpusilla* (IISR, PAU & CCSHAU)
3. Field evaluation of *T. chilonis* against plassey borer (AAU (J))
4. Demonstration on the use of *T. chilonis* (temperature-tolerant strain) against early shoot borer at two locations (PAU)
5. Biological suppression of white grubs using FYM enriched with *Beauveria bassiana* (GBPUA&T)
6. Biological control of the sugarcane woolly aphid (SWA)

-Population dynamics of SWA and its natural enemies (TNAU, AAU (J), ANGRAU & CCSHAU)

-Mass production of predators in shade net/ laboratory *Dipha aphidivora* (MPKV, SBI (in lab)) *Micromus igorotus* (PDBC, TNAU)

-Effect of Agronomic Practices on incidence of SWA (TNAU, MPKV, SBI and ANGRAU)

-Field release and evaluation of *Dipha aphidivora* (AAU (Navsari), TNAU, ANGRAU & SBI) *Micromus igorotus* (TNAU)

-Interaction between *Dipha aphidivora* and *Micromus igorotus* (TNAU, PDBC)

-Field demonstration of biocontrol using *D. aphidivora* and *M. igorotus* (TNAU, MPKV, SBI, AAU (J), ANGRAU, AAU (Navsari) and PDBC)

-Life table studies of SWA and its predators (MPKV, TNAU)

-Development of IPM strategy (TNAU, SBI, IISR, AAU (Navsari), ANGRAU)

-Colonization of *Encarsia flavoscutellum* (TNAU, IISR, AAU (J), ANGRAU, AAU (Navsari)

-Monitoring and forecasting of SWA (TNAU, SBI, IISR, ANGRAU & NCIPM)

-Yield loss assessment (SBI and IISR)

-Roving survey for assessment of impact of natural enemies of SWA in Maharashtra (MPKV TNAU, ANGRAU)

-Assessment of activity of *Micromus* in relation to abiotic factors (PDBC)

III. BIOLOGICAL SUPPRESSION OF COTTON PESTS

1. BIPM for *Bt* cotton (ANGRAU, AAU (A), TNAU, MPKV and PAU)
2. Natural enemy complex of all pests including bollworms, *Spodoptera*, sap-sucking pests and other bugs in *Bt* & non-*Bt* cotton varieties & hybrids (at least two each for the Zone) (ANGRAU, AAU (A), TNAU, UAS (D) and PAU)
3. Enhancement of Natural Enemies Population in cotton by habitat manipulation (PAU, ANGRAU and AAU (A))

IV. BIOLOGICAL SUPPRESSION OF TOBACCO PESTS

1. Biological control of *Spodoptera exigua* in tobacco nurseries with biopesticides (CTRI)

2. Validation of trap crop and border crop modules for the management of lepidopteran pests on tobacco (CTRI)

3. Studies on the efficacy of adjuvants in *Sl* NPV/*Ha*NPV persistence and their impact on tobacco quality (CTRI)

4. Biological control of plant parasitic nematode, *Meloidogyne* spp. in tobacco nurseries (CTRI, Hunsur Station)

V. BIOLOGICAL SUPPRESSION OF PULSE CROP PESTS

1. Evaluation of DOR *Bt* against the pod borers (TNAU, ANGRAU, AAU (A) and UAS (D))

2. Evaluation of BIPM package on soybean (CTRI and NRCS)

VI. BIOLOGICAL SUPPRESSION OF RICE PESTS

1. Evaluation of DOR *Bt* against leaf folder (KAU, GBPUA&T, AAU (J) and PAU)

2. Validation of bio-intensive pest management practices in organic rice production (PAU, KAU, AAU (J), GBPUA&T and NCIPM)

3. Validation of BIPM practices against pest complex of rice (KAU)

VII. BIOLOGICAL SUPPRESSION OF PESTS OF MAIZE

1. Control of cutworm *Agrotis ipsilon* on maize with EPN (SKUAS&T in collaboration with PDBC)

VIII. BIOLOGICAL SUPPRESSION OF OILSEED CROP PESTS

1. Identification of natural enemies of mustard saw fly for use in biocontrol (AAU (A) and AAU (J))

2. Laboratory screening for susceptibility to DOR-5 (*Bt*) and other commercial Bt products and work out LC_{50} following standard leaf disc bioassay method.

3. Biological Control of mustard saw fly (AAU (A) and AAU (J))

IX. BIOLOGICAL SUPPRESSION OF COCONUT PESTS

1. Evaluation of *Trichogramma embryophagum*, *Goniozus nephantidis* & *Cardiastethus exiguus* against *Opisina arenosella* (KAU)

2. Validation of biological suppression of *Oryctes rhinoceros* in homestead garden (KAU)

3. Field evaluation of new formulations of *Hirsutella thomsonii* against coconut mite (PDBC, KAU, ANGRAU, TNAU, CPCRI & 4 centres under AICRP Acarology Project)

4. Biological control of *O. arenosella* using *Bracon* spp. (CPCRI)

5. Field studies on management of *Oryctes* through integration of Green muscardine fungus (GMF), *Oryctes* Baculovirus (OBV) and attractant baited pheromone traps (CPCRI)

6. Laboratory assessment of interactions between *Opisina* parasitoids (CPCRI)

X. BIOLOGICAL SUPPRESSION OF PESTS IN TROPICAL FRUITS

1. Population dynamics of soft green scale *Coccus viridis* and its natural enemies on sapota (IIHR)

2. Field evaluation of natural enemies against mango hoppers (IIHR)

3. Effect of off-season release of *Cryptolaemus montrouzieri* to suppress the mealybug on custard apple on the main season (IIHR)

4. Toxicity of newer pesticides to *Cryptolaemus montrouzieri* (IIHR)

5. Studies on the natural enemies of thrips on pomegranate, mango and grapes (IIHR)

6. Evaluation of *Bt* formulations against leaf miner on acid lime and pomello (IIHR)

7. Mass rearing of *Encarsia guadeloupae* on spiralling whitefly (IIHR)

8. Collection and identification of the natural enemies of sapota seed borer, *Trymalitis margarias* and mango fruit fly *Bactrocera dorsalis* (IIHR)

9. Survey and biocontrol of Guava fruit borer *Conogethes punctiferalis* (RARS, UAS (D), Raichur)

10. Protocol for demonstration of biological control of pink mealy bug, *Maconellicoccus hirsutus* on grapevine with *Cryptolaemus montrouzieri* (NRC on grapes, AICRP on Biological Centre, MPKV, Pune under the technical guidance of IIHR and PDBC)

XI. BIOLOGICAL SUPPRESSION OF PESTS OF TEMPERATE FRUITS

1. Development of bio-intensive IPM for San Jose Scale, *Quadraspidiotus perniciosus* in apple ecosystem. (SKUAS&T)
2. Field evaluation of *Trichogramma embryophagum* against the codling moth, *Cydia pomonella* on apple (SKUAS&T)
3. Evaluation of fungal pathogens against root infesting woolly aphids (Dr.YSPUH&F) and mites (SKUAS&T) on apple
4. Mass production of predatory mites (Dr.YSPUH&F)
5. Study on the efficacy of fungus isolated from the defoliating beetle, *Brahmina coriacea* (Dr.YSPUH&F)
6. Evaluation of some microbial agents against apple root borer, *Dorysthenes hugelii* (Dr.YSPUH&F)
7. Control of edaphic populations of woolly apple aphid using EPN (Dr.YSPUH&F in collaboration with PDBC)
8. Control of codling moth *Cydia pomonella* (Lepidoptera: Tortricidae), with *Steinernema carpocapsae* (SKUAS&T, Srinagar in collaboration with PDBC)

XII. BIOLOGICAL SUPPRESSION OF PESTS OF VEGETABLE CROPS

1. Biological control of *Diaphania indica* infesting gerkhins/cucurbits (IIHR)
2. Biological control of DBM on cabbage / cauliflower (IIHR, IIVR)
3. Evaluation of EPN against brinjal shoot and fruit borer (IIHR, KAU, PAU, IIVR)
4. Standardization of mass rearing of *Thrips tabaci* (IIHR)
5. Feeding potential of *Orius tantillus* on chilli thrips (IIHR)
6. Mass multiplication and evaluation of *Diadegma fenestralis* (Dr.YSPUH&F)
7. Microbial control of *Trialeurodes vaporariorum* using fungal pathogen (Dr.YSPUH&F)
8. Evaluation of DOR *Bt* against fruit borers of brinjal and okra (KAU & PAU)
9. Effectiveness of various microbial pesticides and a summer oil against *Pieris brassicae* (Lepidoptera: Pieridae) on kale/ knol khol (SKUAS&T)
10. Development of biocontrol based IPM module against cabbage pests (SDAU)
11. Evaluation of *Trichogramma brassicae* alone and in combination with *Bt* against lepidopteran pests of cole crops (cabbage/ cauliflower) (TNAU, ANGRAU, IARI, SKUAS&T (K), SKUAS&T(J), Dr.YSPUH&F, IIHR)
12. Biological suppression of white grubs using FYM enriched with *Beauveria bassiana* and *Metarhizium anisopliae* (GBPAU & T)
13. Biological control of Potato Tuber Moth by releasing *Copidosoma koehleri* (AAU(J))

XIII. BIOLOGICAL SUPPRESSION OF PESTS IN TURF GRASS

1. Microbial control of white grubs in turf (SKUAS&T and GBPUA&T-Ranichauri Centre)

XIV. BIOLOGICAL SUPPRESSION OF PESTS IN POLYHOUSES

1. Biological control of thrips, aphids and mites in polyhouses (MPKV, KAU and NCIPM)

XV. BIOLOGICAL SUPPRESSION OF WEEDS

1. Survey for the natural enemies of *Cyperus rotundus* (KAU, TNAU, AAU (A), AAU (J), PAU and NRCWS)
2. Evaluation of *Cecidochares connexa* against *Chromolaena odorata* (KAU & AAU(J))

XVI. ESTABLISHMENT OF MASS PRODUCTION UNITS (AT ALL THE AICRP CENTRES)

13. CONSULTANCY, PATENTS AND COMMERCIALISATION OF TECHNOLOGY

- EAG and GC-MS analysis for samples received from various organizations
- Quality test for several biopesticides
- Bioassay of *Bt* proteins against lepidopterous pests
- Simple design and technology for development of amorphous (talc) formulations of antagonistic fungi
- Methodology of mass multiplication of *Pseudomonas fluorescens* on cowdung (GBPUA&T) – submitted for patenting

14. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE

Eleventh Research Advisory Committee Meeting held on 14 July 2006

The Chairman and the RAC Members expressed satisfaction and happiness over the achievements made by the scientists. The following recommendations emerged at the end of the discussion:

1. Identification of two or three centres for large-scale production and supply of *Helicoverpa armigera*.
2. Strengthening of research in biological suppression of brinjal fruit and shoot borer.
3. Developing technology for storage of biocontrol agents.
4. More stress need to be given on use of biological control agents on crops grown in dry farming area.
5. Data base on the utilization of biocontrol agents on different crops along with area.
6. Research activity on the biological suppression of coconut mite should continue.
7. A Transfer of Technology cell needs to be created in the XI Plan for effective dissemination of knowledge generated in biological control.
8. Mass production of selected biocontrol agents to be started at village level with the participation of the farmers.
9. While formulating the programmes in the XI Plan priority to be given for the biological suppression of pests of national importance and polyphagous nature.
10. Significant efforts are to be made for the management of pests in protected cultivation and export-oriented crops/commodities.
11. Research activity need to be strengthened in the field of storage pests.
12. Training in significant areas can be identified for the HRD development.
13. The present centre in the north eastern region (AAU, Jorhat) may not be able to help the entire region hence establishment one or two centres can be proposed in the NEH

region preferably in states like Manipur and Sikkim.

14. Proposal may sent to the council to create the posts sanctioned in IX and X Plans

Institute Research Council Meeting held from 4-5 May 2006

The Institute Research Council Meeting of PDBC, Bangalore was held under the Chairmanship of Dr. R. J. Rabindra, Project Director, in the presence of Dr. T. P. Rajendran, Assistant Director General (PP), ICAR, New Delhi attended the two-day meeting.

Dr. R. J. Rabindra, Project Director welcomed all. The scientist then presented the results of the research projects and after each presentation detailed discussions followed. The specific recommendations/comments for taking further action are as follows:

- Distribution map for common species of coccinellids may be made with the available resource – Dr. J. Poorani
- Dr. S. Ramani is required to close down the project on Biosystematics study on Tachinidae and submit a new project proposal on 'Biodiversity'– Dr. S. Ramani
- Small plots can be irrigated where *Chromolaena* grows for getting new flushes for attracting in oviposition by tephritid fly. *Trichogramma mwanzai* can be tried in other ecosystem for its usefulness if not getting encouraging results in pulses ecosystem. *Trichogramma brassicae* can be tried under field conditions against diamond back moth. Success story on biological control of weeds particularly in Andhra Pradesh, Tamil Nadu, Kerala, Karnataka & Goa can be doumented – Dr. B. S. Bhummannavar
- Studies on biological control on storage pests can be taken right from the field to the storage structures for releasing anthocorids– Dr. C. R. Ballal
- Distribution pattern of sugarcane woolly aphid along with various weather factors in different agro-climatic conditions may be taken up for further correlation studies. Food source for the wooly aphid may be identified in the off-season – Dr. Prashant Mohanraj
- Flowers and fruits of *Chenopodium* can also be used for identifying any kairomonal or synomonal compound. Kairomones for anthocorids can be identified for rose, bhendi and cabbage – Dr. P. L. Tandon
- Field trials taken up by the AICRP centres/ voluntary centres should be under the direct supervision of the concerned scientist to get first hand information. Instead of writing kairomones, the chemical name should be spelled out clearly. Stabilizers used in the formulation also need to be evaluated individually as well as in combination – Dr. N. Bakthavatsalam
- Finger printing for Endogram (endosulfan tolerant strain of *Trichogramma chilonis*) and strain variation, molecular characterization need to be strengthened – Dr. S. K. Jalali
- Constraints need to be specified before and after storage of artificial diets – Dr. K. Srinivasa Murthy
- Arrangements may be made to release the CD on biological suppression of rice pests – Mr. S. R. Biswas & Dr. N. S. Rao
- The ICAR – PDBC website need to be upgraded – Ms. M. Pratheepa & Dr. K. Srinivasa Murthy
- Chemical structure of the Tinopal need to be known before use along with NPV – Dr. K. Veenakumari
- Rapid method for quality analysis need to be standardized for antagonists – Dr. S. Sriram & Dr. R. Rangeshwaran
- The present project on biological control of phytophagous mites can be continued and coconut mite work need to be included in the same project – Dr. P. Sreerama Kumar
- EPN need to be tried in different crop eco-system with the help of Project Co-ordinator on AICRP on Nematology. Shelf life experiments need to be continued – Dr. S. S. Hussaini
- Risk involved in handling *Paecilomyces*

lilacinus may be looked into – Dr. M. Nagesh

- The RPF I for new project submitted by different scientists need to be circulated amongst all the scientist at PDBC to obtain their views and after incorporation of the suggestions may be submitted for the approval – Dr. N. S. Rao

The Institute Research Council Meeting held on 5 January 2007

The Institute Research Council Meeting of PDBC, Bangalore was held under the Chairmanship of Dr. R. J. Rabindra, Project Director. The scientists presented the report on the targets achieved for the period 01-07-2006 to 31-12-2006. The Project Director apprised the Council's concern on addressing the visibility of technology transfer of mass production of biocontrol agents, linkage with AICRP's of Crop Sciences and Horticulture Divisions and crop health management in the future programmes of XI Plan.

After the detailed discussion on the presentation of the achievements as per the targets given in their respective projects following points emerged out as recommendations.

- Import permit was obtained for several natural enemies, but only a few were imported. A justification has to be placed on record for not importing some of the natural enemies. Revised list may be prepared on the import of natural enemies for inclusion in the XI Plan proposals. Agents like *Heteropsylla spinulosa* and *Anagyrus kamali* to be included in the list for importation – Dr. B.S. Bhumannavar
- Effectiveness of adjuvants for *Sl*NPV may be evaluated in tomato. Work on *Aa*NPV and *So*NPV to continue – Dr. K. Veenakumari
- Castor, *Chenopodium* and capsicum crops may be tried as intercrop along with tomato on the incidence of *Helicoverpa armigera* – Dr. P.L.Tandon
- Bunny variety in cotton may be included in the field trials and delete further experiments with *Campoletis chlorideae*, Waste products from the production units like moth scales, frass, etc. may be studied for utility as kairomones – Dr. N. Bakthavatsalam
- Efficacy of *Trichogramma* spp. may be evaluated against eggs of hairy caterpillars like *Amsacta albistriga* and *Spilarctia obliqua* – Dr. S.K. Jalali
- Work on biosystematics of *Trichogramma* to be intensified. The percentage parasitisation of sugarcane woolly aphid by *Encarsia flavoscutellum* to be worked out. Work on production of *Dipha aphidivora* on semi-synthetic diet should be intensified – Dr. Prashant Mohanraj
- Cost of production of *Micromus igorotus* may be worked out – Dr. Sunil Joshi
- In the field trials against coconut mite, conidia along with mycelia (hyphae) of *Hirsutella thompsonii* with and without adjuvants may be evaluated in a concurrent trial – Dr. P. Sreerama Kumar
- Number of locations of cotton growing areas are to be increased substantially for collection of *Chrysoperla carnea* representing geographical regions to ensure a broad genetic base – Dr. T. Venkatesan
- Number of locations has to be increased substantially for collection of *Goniozus nephantidis* representing different coconut areas in various geographical regions. Cultures of *Helicoverpa armigera* may be initiated from embryos – Dr. K. Srinivasa Murthy
- Studies on interaction between *D. aphidivora*, *M. igorotus* and *E. flavoscutellum* of sugarcane woolly aphid need to be intensified. Since the grapevine mealy bug is becoming serious, studies on the interaction of *Cryptolaemus montrouzieri* and mealy bug parasitoids may be initiated – Dr. S. Ramani
- A list of natural enemies and host insects to be maintained in the national repository may be prepared – Dr. N.S. Rao
- Work on anthocorids may be further intensified. Since, *C. chlorideae* cannot be cultured in a large scale commercially, the

maintenance of the culture may be discontinued – Dr. C.R. Ballal

- Nitrogen enhancing the CFU in storage has to be verified, Efforts are to be intensified on developing oil/liquid-based formulations – Dr. B.Ramanujam
- Indigenous *Bt* strains may be evaluated against okra fruit borer, brinjal shoot and fruit borer, rice leaf folder, maize stem borer, pink borer, pink bollworm and red hairy caterpillars – Dr. R. Rangeshwaran
- Studies on shelf-life should be continued for 12 months – Dr. S. Sriram
- In addition to CFU and bioefficacy, contaminant microbial load also should be studied – Dr. B. Ramanujam and Dr. S. Sriram

Institute Management Committee Meetings

The Chairman welcomed all the Members to the Thirteenth Management Committee held on 4 May 2006 at the PDBC, Bangalore.

After a brief introductory remarks and progress made by the Project Director, the agenda items were taken up for discussion.

The Action taken on the recommendation of XII Management Committee meeting held on 11 August 2005 at PDBC, Bangalore was presented for the kind information of the Management Committee.

I. Action taken report of 12th Management Committee Meeting

1. Farm development

Additional of Rs.150 lakhs for farm work like road, street lights, compound wall, irrigation facilities, drainage channels and other miscellaneous items

Action taken: Projected in the revised EFC submitted to ICAR

2. Equipment

Inclusion of following equipment in the revised EFC:

Incubator shaker costing Rs.5.00 lakhs

Table-top centrifuge costing Rs.4.50 lakhs

Other smaller equipment based on need

Action taken : As per the advise of ADG (PIM), ICAR these items are to be proposed in the next plan EFC

Recommendation : The committee adopted the action taken report of the 12th Management Committee Meeting.

II. Agenda items for recommendation by IMC

a) Renovation of existing Nematology building costing Rs. 29.443 lakhs proposed under Non-Plan under the head Special Repairs and Maintenance – AA and ES – Ratification

In anticipation of post-facto approval of the IMC, administrative approval and expenditure sanction was accorded for an amount of Rs.29.443 lakhs to the CPWD for the repairs and renovation of the Nematology biocontrol building by replacement of the asbestos roof with RCC roof on pillars, since the amount had to be deposited with the CPWD before 31.3.2006. Since the amount exceeds Rs. 25.00 lakhs over and above the powers of the Project Director, the ratification of the IMC is sought.

The details of estimates received from CPWD is appended as Annexure I.

Recommendation: After detailed discussion, the committee has ratified the renovation of existing Nematology building costing Rs.29.443 lakhs as per the estimate provided by the CPWD.

Recommendation: After detailed discussion, the committee has recommended for replacement of equipments in place of condemned equipments subject to condition that these items are to be condemned by a duly constituted committee. For environmental chambers, the committee suggested to find out the possibilities of repairing the item by exploiting the local expertise available. It was also suggested that replacement of colour monitor can be explored through buy-back scheme.

c) Consultancy charges for the experts under the consultancy project DOW Agro Sciences Mumbai

   Recommendation: After detailed discussions, the committee agreed for payment of consultancy charges subject to the recommendations of the Consultancy Processing Cell of the Institute.

d) Proposal for additional sanction under different item of work under Farm Development as well as equipment.

At the time of submission of EFC proposal, the UAS, Bangalore had agreed to spare 10 acres of land for developing the farm for PDBC and an allocation of Rs.100 lakhs was approved under the X Plan EFC for farm development. However, subsequently the university has handed over 25 acres of land on lease to the PDBC. Out of sanctioned amount we have listed 15 items. Now we need additional sanction for the following items of work.

Farm development

(Rs. in lakhs)

S. No.	Item of work	Sanctioned in X plan	Additional sanction required
1.	Water harvesting system & drainage channels	6.00	3.95
2.	Street lights	1.50	1.13
3.	Compound wall & road	14.50	7.50
4.	Glasshouse (5x5 m)	5.00	0.10
5.	C/o Farm Office, Store room and Field Laboratories	18.50	0.70

Recommendation: After detailed discussion, the committee has recommended for the additional sanction under works and equipment.

Interactive meeting with industries on Commercial-Scale Production of Biocontrol Agents – Validation Technologies, 22 January 2007

An interactive meeting with private and public sector enterprises dealing with commercial scale production of biocontrol agents was held at PDBC, Bangalore on 22 January 2007.

Sixteen delegates representing various commercial scale production units attended the meeting and took part in discussions in the interactive meeting.

The technologies developed by the PDBC scientists were presented mainly on simple design for small-scale solid-state mass production of antagonistic fungi and technology for development on talc formulations; technology for production, formulations and application of entomopathogenic nematodes; mass production of baculoviruses with particular reference to *Aa*NPV, *Sl*NPV and *Px*GV; improved talc based formulation for *Pseudomonas fluorescens* and *Bacillus subtilis*; liquid fermentation technology for production of *Beauveria bassiana* and *Nomuraea rileyi*; commercial production of *Telenomus remus* and anthocorids; availability of multiple insecticidal tolerant strain and high temperature tolerant strain of *Trichogramma chilonis*; production and use of *Goniozus nephantidis* against coconut leaf eating caterpillar; production of *Chrysoperla carnea* using semi-synthetic diet and kairomones formulation to increase efficiency of chrysopids and trichogrammatids

During the interaction, the entrepreneurs indicated their interest in collaborative research and development under public/private sector partnership (PPP) mode in the areas.

S.No.	Entrepreneur	Areas of interest
1	Biotech International Ltd., New Delhi	*Beauveria bassiana* for coffee berry borer
2	Multiplex Bio Tech Pvt. Ltd., Bangalore	Fungal pathogens for sucking pests and also requested that the scientists of PDBC should visit their production unit for inspecting the facilities created and assessing their potential for PPP
3	Plantrich Chemicals & Fertilisers Ltd., Kottayam	*Beauveria bassiana, Metarhizium anisopliae, Pseudomonas*
4	Sudharshan Chemicals Ltd., Pune	Solid state fermentation of *Beauveria bassiana*
5	Biocontrol Research Laboratories, Bangalore	Production package for *Bacillus subtilis, Verticillium lecanii*
6	SOM Phytopharma (India) Ltd., Bollaram, Hyderabad,	EPN, Solid state fermentation and data package for 9(3) registration for *Bacillus subtilis*

Further, some of the companies wanted transfer of technology for the following biocontrol agents for production and formulation along with bioefficacy and toxicological data for registration.

S. No.	Company	Agents
1	Biocontrol Research Laboratories, Bangalore	*M. anisopliae, Verticillium lecanii, B. subtilis, B. bassiana* for coffee berry borer
2	Plantrich Chemicals & Fertilisers Ltd., Kottayam	*B. bassiana, M. anisopliae, B. subtilis*
3	Sudharshan Chemicals Ltd., Pune	*B. bassiana, M. anisopliae, V. lecanii*
4	K. N. Biosciences (India) Pvt. Ltd., Hyderabad	*B. bassiana, M. anisopliae, V. lecanii*
5	Biotech International Ltd., New Delhi	*B. bassiana* for coffee berry borer

In order to promote biocontrol research with focus on enhanced uptake of quality biocontrol agents, the following potential research areas relevant to industries were identified.

1. Need for strain specification as well as development of location-specific biocontrol agents
2. Refinement of fermentor production of fungal agents.
3. Development of oil based formulation of biocontrol agents particularly fungal biocontrol agents to overcome the low Rh and enhance shelf life, field persistence and efficacy.
4. Delivery and release methodology for biocontrol agents
5. Microbial contaminant control in formulations

15. PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA, ETC. IN INDIA AND ABROAD

Project Directorate of Biological Control, Bangalore

Dr. R. J. Rabindra

NAIP Training Workshop on Value Chains, TNAU, Coimbatore, 5-9 June 2006.

National Seminar on Potential and Prospects of Organic Farming in North East, ICAR Research Complex for NEH Region, Barapani, 30-31 October 2006.

National Seminar on Organic Crop Protection Technologies for Promoting Export Market-linked Agri-Horticulture in India, Sun Agro Biotech Research Centre, Chennai, 21 November 2006.

Directors' Conference of ICAR Institutes, New Delhi, 3-5 November 2006.

Meeting of The Expert Group for Review of Guidelines for Registration of Biopesticides, New Delhi, 17 April 2006.

Group Meeting on Re-orientation of Entomology Research in CPCRI and AICRP on Palms, CPCRI, Kasaragod, 16 June 2006.

Meeting of Mealybugs on Grapes, NRC Grapes, Pune, 12 June 2006.

Task Force Meeting of the Department of Biotechnology, New Delhi, 10 October 2006.

Seventh Annual Discussion Meeting in Entomology on Semiochemicals in Crop Protection: Ongoing Technologies, Chennai, 2 December 2006.

Second Meeting of the Expert Group for Review of Guidelines for Registration of Bio-pesticides, Directorate of Plant Protection, Quarantine and Storage Central Insecticides Board and Registration Committee, Faridabad, 19 December 2006.

Annual Group Meeting of Network Project on Organic Farming, Project Directorate on Cropping Systems Research, Modipuram, 27-28 December 2006.

Meeting on Biological Control of Grapevine Mealybug, National Research Centre for Grapes, Pune, 9 January 2007.

RAC Meeting of the NCIPM, New Delhi, 10-11 January 2007.

QRT Meeting of the NRCW, Jabalpur, 28-30 January 2007.

NAIP Meeting on Business Planning and Development, New Delhi, 12 February 2007

Brainstorming Session on IPM and Biocontrol, New Delhi, 26 April 2006.

DBT Meeting of Public Private Partnership R& D Programme on Biological Control, Pune, 12 May 2006.

Brainstorming Session on Projectized Mode of Research in ICAR, National Centre for Agricultural Economics and Policy Research, New Delhi, 19 July 2006.

RAC meeting of CITH, Srinagar, 23 July 2006.

Dr. P.L. Tandon

Fifteenth Biocontrol Workers' Group Meeting, PDBC, Bangalore, 24-25 May 2006.

Interactive Meeting with Industry on Commercial Scale Mass Production of Biocontrol Agents-Validation of Technologies, PDBC, Bangalore, 22 January 2007.

Dr. B.S. Bhumannavar

Fifteenth Biocontrol Workers' Group Meeting on Biological Control of Crop Pests and Weeds, PDBC, Bangalore, 24-25 May 2006.

Seventh International Workshop on Management and Biological Control of *Mikania micrantha* and *Chromolaena odorata* at National Pingtung University of Science and Technology, Taiwan 12-15 September 2006.

DST Sponsored Programme on Project Formulation, Implementation & Evaluation, Administrative Staff College of India, 19 February - 2 March 2007.

Dr. K. Veenakumari

Fifteenth Biocontrol Workers' Group Meeting on Biological Control of Crop Pests and Weeds, PDBC, Bangalore, 24-25 May 2006

Interactive Meeting on Guidelines for Registration of Biopesticides, PDBC, Bangalore, 5 October 2006.

Brainstorming Session on Status, Prospects and Road Map of Enhancing the Uptake of Antagonistic Organisms in Nematode Management in India, PDBC, Bangalore, 17-18 November 2006.

Interactive Meeting on Commercial Scale Mass Production of Biocotnrol Agents-Validation of Technologies, PDBC, Bangalore, 22 January 2007.

Dr. S. Ramani

Fifteenth Biocontrol Workers' Group Meeting, PDBC, Bangalore, 24-25 May 2006

Symposium on Biological Control of Sucking Pests, Institution of Agricultural Technologists, Bangalore, from 5-6 May 2006.

Dr. Chandish R. Ballal

Fifteenth Biocontrol Workers Group Meeting, PDBC, Bangalore, 24-25 May 2006.

National Symposium on Biological Control of Sucking Pests, Institution of Agricultural Technologists, Bangalore, 26-27 May 2006.

Regional Workshop on Strategies for Improving the Performance of Farming Systems in Rainfed Areas, MANAGE, Hyderabad, 14-16 June 2006.

Brainstorming Session on Pests and Diseases of Onion and Garlic, NRCOG, Rajgurunagar, 16- 17 January 2007.

Interactive Meeting on Commercial Scale Production of Biocontrol Agents – Validation of Technologies, PDBC, Bangalore, 22 January 2007.

SPSS Data Analysis Seminar, SPSS and Keonics, Hotel Chancery, Bangalore, 2 March 2007.

Dr. Prashanth Mohanraj

Special Workshop on the Contract Labour (Regulation & Abolition) Act 1970, Hotel Taj Residency, Bangalore, 28-29 June 2006.

Dr. T. Venkatesan

Fifteenth Biocontrol Workers' Group Meeting, PDBC, Bangalore, 24-25 May 2006.

Dr. P. Sreerama Kumar

Fifteenth Biocontrol Workers' Group Meeting, PDBC, Bangalore, 24-25 May 2006.

National Symposium on Biological Control of Sucking Pests, Society for Biocontrol Advancement, Bangalore, 26-27 May 2006.

Twelfth International Congress of Acarology: Symposium on Diseases of Mites and Ticks, University of Amsterdam, Amsterdam, The Netherlands, 21-26 August 2006.

Interactive Meeting on Guidelines for Registration of Biopesticides, PDBC, Bangalore, 5 October 2006.

National Seminar on Patenting in Biotechnology, Hotel Taj Banjara, Hyderabad, 26 October 2006.

Brainstorming Session on Status, Prospects and Road Map for Enhancing the Uptake of Antagonistic Organisms in Nematode Management in India, PDBC, Bangalore, 17-18 November 2006.

Interactive Meeting on Commercial-scale Mass Production of Biocontrol Agents- Validation of Technologies, PDBC, Bangalore, 22 January 2007.

Tenth Group Meeting of the All-India Network Project on Agricultural Acarology, Navsari Agricultural University, Navsari, 27-28 February 2007.

Group Meeting on ICAR-CABI Collaborative Project Classical Biological Control of *Mikania micrantha* with *Puccinia spegazzinii*: Implementation Phase, National Bureau of Plant Genetic Resources, Pusa, New Delhi, 5 March 2007.

Dr. Sunil Joshi

National Seminar on Changing Global Vegetable Oils Scenario: Issues and Challenges Before India, Hyderabad, 29-31 January 2007.

SPSS Data Analysis Seminar, SPSS South Asia Pvt. Ltd. and KEONICS, 2 March 2007.

Dr. R. Rangeshwaran

Fifteenth Biocontrol Workers' Group Meeting, PDBC, Bangalore, 24-25 May 2006.

Interactive Meeting on Guidelines for Registration of Biopesticides, PDBC, Bangalore, 5 October 2006.

Brainstorming Session on Status, prospects and Road Map of Enhancing the Uptake of Antagonistic Organisms in Nematode Management in India, PDBC, Bangalore,17-18 November 2006.

Interactive Meeting on "Commercial Scale Mass Production of Biocontrol Agents" – Validation of Technologies", PDBC, Bangalore, 22 January 2007.

Visit of Project Director to different AICRP Centres

The Project Director visited different centres of the All-India Co-ordinated Project on Biological Control of Crop Pests and Weeds to review the progress of work, layout of field experiments, to understand the difficulties and to resolve problems faced in the implementation of the different technical programmes. The centres visited with dates are as under:

1. AICRP centre at College of Agriculture, Pune, 12 May 2006.
2. AICRP centres at TNAU and SBI Coimbatore, 9 June 2006.
3. AICRP centre at PAU, Ludhiana, 30 June 2006.
4. AICRP Centre at KAU, Thrissur, 10 July 2006.
5. AICRP centres at TNAU and SBI Coimbatore, 11 July 2006.
6. AICRP centre at GBPUAS & T, Pantnagar, 21 July 2006.
7. AICRP centre at SKUAS & T, Srinagar, 22 July 2006.
8. AICRP centre at ANGRAU, Hyderabad, 25 August 2006.
9. AICRP centre at Dr.YSPUH & F, Solan, 31 August 2006 and 1 September 2006.
10. AICRP centre at CTRI Rajamundry, 26 September 2006.
11. AICRP centre at Anand Agricultural University, Anand, Gujart, 23 December 2006.
12. AICRP centre at IISR, Lucknow, 12 January 2007.
13. AICRP centre at TNAU, Coimbatore, 2 February 2007.
14. AICRP centre at AAU, Jorhat, 20 February 2007.

16. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, ETC.

Organized at PDBC

- Institute Management Committee Meeting: 4 May 2006
- XV Biocontrol Workers' Group Meeting: 24-25 May 2006
- Institute Research Council Meeting: 4-5 May 2006 & 5 January 2007
- Twelfth Research Advisory Committee Meeting: 14 July 2006
- National Symposium on Biological Control of Sucking Pests: 26-27 May 2006
- Workshop on Guidelines for Registration of Biopesticides: 5 November 2006
- Group Discussion on Status, Prospects and Road Map of Enhancing the Uptake of Antagonistic Organisms in Nematode Management in India: 17-18 November 2006
- Commercial-Scale Mass Production of Biocontrol Agents – Validation of Technologies: 22 January 2007.

Celebrated

- ICAR Foundation Day: 17 July 2006
- World Food Day: 16 October 2006
- Quami Ekta Week: 20-25 November 2006

17. DISTINGUISHED VISITORS

Project Directorate of Biological Control, Bangalore

Mr. A. K. Upadhyay, Additional Secretary, DARE & Secretary, ICAR, New Delhi on 18 November 2006

Ms. Rita Sharma, Additional Secretary and Financial Advisor, DARE, New Delhi on 8 December 2006

Assam Agricultural University, Jorhat

Dr. Mangala Rai, Secretary, DARE & Director-General, ICAR, New Delhi

18. PERSONNEL

Project Directorate of Biological Control, Bangalore

Dr. R. J. Rabindra	Project Director
Dr. P. L. Tandon	Principal Scientist
Dr. N. S. Rao	Principal Scientist
Dr. S. R. Biswas	Principal Scientist
Dr. S. S. Hussaini	Principal Scientist
Dr. B. S. Bhumannavar	Principal Scientist
Dr. N. Bakthavatsalam	Senior Scientist
Dr. (Ms.) Chandish R. Ballal	Senior Scientist
Dr. S. Ramani	Senior Scientist
Dr. S. K. Jalali	Senior Scientist
Dr. B. Ramanujam	Senior Scientist
Dr. Prashanth Mohanraj	Senior Scientist
Dr. M. Nagesh	Senior Scientist
Dr. (Ms.) Veenakumari	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
Dr. Sunil Joshi	Scientist (SS)
Dr. R. Rangeshwaran	Scientist (SS)
Dr. S. Sriram	Scientist (SS)
Ms. M. Pratheepa	Scientist (SS)
Dr. (Ms.) Deepa Bhagat	Scientist (SS)

Central Tobacco Research Institute, Rajahmundry

Mr. S. Gunneswara Rao	Scientist (SG)
Dr. P. Venkateswarlu	Senior Scientist

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Dr. (Ms.) Chandrika Mohan	Senior Scientist

Indian Agricultural Research Institute, New Delhi

Dr. G. T. Gujar	Principal Scientist

Indian Institute of Sugarcane Research, Lucknow

Dr. Arun Baitha	Scientist (SS)

Indian Institute of Horticultural Research, Bangalore	
Dr. A. Krishnamoorthy	Principal Scientist
Dr. (Ms.) P. N. Ganga Visalakshy	Senior Scientist
Sugarcane Breeding Institute, Coimbatore	
Dr. J. Srikanth	Senior Scientist
Anand Agricultural University, Anand	
Dr. D. N. Yadav	Principal Research Scientist
Dr. D. M. Korat	Principal Research Scientist
Dr. J. J. Jani	Assistant Research Scientist
Acharya N. G. Ranga Agricultural University, Hyderabad	
Dr. A. Ganeswara Rao	Principal Scientist
Dr. S. J. Rahman	Senior Scientist
Assam Agricultural University, Jorhat	
Dr. A. Basit	Principal Scientist
Dr. D. K. Saikia	Senior Scientist
Dr. Y. S. Parmar University of Horticulture & Forestry, Solan	
Dr. P. R. Gupta	Senior Entomologist
Dr. Anil Sood	Assistant Entomologist
Govind Ballabh Pant University of Agriculture & Technology, Pantnagar	
Dr. U. S. Singh	Professor
Dr. (Ms.) Nijam Waris Zaidi	Training Associate
Kerala Agricultural University, Thrissur	
Dr. (Ms.) S. Pathummal Beevi	Associate Professor
Dr. (Ms.) K. R. Lyla	Associate Professor
Mahatma Phule Krishi Vidyapeeth, Pune	
Dr. S. A. Ghorpade	Entomologist
Dr. D. S. Phokharkar	Assistant Entomologist
Punjab Agricultural University, Ludhiana	
Dr. S. Maninder	Senior Entomologist
Dr. (Ms.) Neelam Joshi	Assistant Microbiologist
Ms. Ramandeep Kaur	Assistant Entomologist
Dr. (Ms.) Rabinder Kaur	Assistant Entomologist
Sher-e-Kashmir University of Agriculture & Technology, Srinagar	
Dr. Abdul Majid Bhat	Entomologist
Tamil Nadu Agricultural University, Coimbatore	
Dr. R. Balagurunathan	Professor
Dr. N. Sathiah	Professor

19. INFRASTRUCTURE DEVELOPMENT

Equipment

The laboratories were further strengthened with the acquisition of several equipment, including, dehumidifier, nitrogen cylinder, camera hood for digital imaging system, fibreoptic lamp, refrigerators and stabilizers, UPS, desktop computers and printers and fax machine.

Library

The library has a collection of 1,828 books, 1,288 volumes of journals, 51 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Twelve foreign and 15 Indian journals were subscribed for. CD-ROM - abstracts upgraded up to February 2007. New CDs on Crop Protection Compendium 2006 edition was procured.

Aris Cell

Norton anti-virus software was procured and installed in 14 computers in the institute. Besides latest version of MS Office 2007, CorelDraw and PageMaker were also installed in Aris cell computers. A new UPS system (5 KVA) was procured. A software for automatic weather station was installed in ARIS cell computers to upload information of weather generated by the automatic weather station installed at the PDBC research farm. A software PERMISNET was installed in ARIS Cell for online biodata information of scientists and other staff of PDBC.

National 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. PDBC's reference collection of insects has been electronically catalogued in a retrievable form.

Laboratories

The Conference Hall was renovated and additional facilities were provided for the Pathology and Nematology laboratories.

Farm development

Construction of compound wall, farm office–cum-field laboratory, implement shed, nethouse and automatic weather station were completed. Drip irrigation to cover a part of the farm was installed.

20. EMPOWERMENT OF WOMEN

During 2006-07, the participation of women in different training programmes was as follows:

Mass Production and Quality Control Aspects of Entomopathogenic Nematodes, Antagonists and Trichogrammatids (25.4.2006 to 4.5.2006)

Ms. Leepa Abraham, Technical Assistant, POABS, Envirotech Pvt. Ltd., Thiruvananthapuram.

Entomopathogenic Nematodes (1.5.2006 to 10.5.2006)

Ms. Shivaleeva, Ph. D. Student, College of Agriculture, Raichur.

Antagonists for Plant Disease Control (18.9.2006 to 26.9.2006)

Ms. P. Sainamole Kurian, Assistant Professor, AICVIP, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala.

Mass Production of Antagonists (11.12.2006 to 16.12.2006)

Dr. P. Raji, Assistant Professor, Regional Agricultural Research Station, Kerala Agricultural University, Pattambi, Kerala.

Molecular Characterization of Insect Pests, Their Natural Enemies and Pathogens (16.1.2007 to 23.1.2007)

Dr. (Ms.) Manju Lata Kapur, Principal Scientist, Division of Plant Quarantine, National Bureau of Plant Genetic Resources, New Delhi.

Dr. (Ms.) T. Jiji, T., Assistant Professor (Entomology), College of Agriculture, Vellayani, Thiruvanthapuram.

Mass Production and Quality Control Aspects of Natural Enemies for Subject Matter Specialists from KVKs of Zone VIII (1.2.2007 to 9.2.2007)

Dr. N. Chithra, Subject Matter Specialist, Krishi Vigyan Kendra, Sandhiyur, Salem, Tamil Nadu.

Mass Production and Quality Control Aspects of Natural Enemies (12.2.2007 to 17.2.2007)

Ms. Gauri Kakad, Krishi Sevika, Biocontrol Lab.,, Aurangabad, Maharashtra.

Ms. Vidya U. Rathod, Krishi Sevika, Biocontrol Lab., Yavatmal, Maharashtra.

Mass Production and Quality Control Aspects of Natural Enemies for Subject Matter Specialists from KVKs of Zone VIII (20.3.2007 to 28.3.2007)

Ms. O. P. Reji Rani, Subject Matter Specialist, Krishi Vigyan Kendra, Kollam, Kerala.

Dr. (Ms.) Roopa, S. Patil, Subject Matter Specialist, Krishi Vigyan Kendra, Davanagere, Karnataka.

Ms. B. Anusha, Subject Matter Specialist, UPASI Krishi Vigyan Kendra, Coonoor, Tamil Nadu.

Ms. Ashalatha, Subject Matter Specialist, MYRADA Krishi Vigyan Kendra, Gobichettipalayam, Tamil Nadu.

Entomopathogenic Nematodes (20.3.2007 to 29.3.2007)

Dr. (Ms.) Aruna Parihar, Associate Professor, Department of Nematology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan.