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2005-06




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जैनियनि
PDBC

PROJECT DIRECTORATE OF BIOLOGICAL CONTROL

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Project Directorate of Biological Control
Bangalore 560 024

Telephone	:	+91-80-23414220, 23511998, 23511982, 23417930
Telegram	:	BIOSUPPRESSION, Bangalore
Fax	:	+91-80-23411961
E-mail	:	pdblc@indiatimes.com; rjrabindra@rediffmail.com
Website	:	http://www.pdblc.com

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Compiled and edited by

Dr. P. Sreerama Kumar
Dr. N.S. Rao
Dr. R.J. Rabindra

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Front cover (clockwise from top left):
Dipha aphidivora larva, *D. aphidivora* adult, *Micromus igorotus* adult and *M. igorotus* larva
Back cover: Sugarcane woolly aphid infestation
(Photos by Dr. Sunil Joshi)

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CONTENTS

1. PREFACE

The Project Directorate of Biological Control (PDBC) since its inception in 1993 has made notable contributions in the field of biological control of crop pests and weeds. It is able to efficiently run the All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds by networking with 16 crop-oriented field centres in different SAUs and ICAR Institutes. While PDBC has focused mainly on basic research, the field centres, with the able support of PDBC, has validated the efficacy of several potential biological control agents as essential components in Biocotrol-based Integrated Pest Management (BIPM) modules for different crop ecosystems. The achievements made by PDBC and the field centres include introduction of potential exotic natural enemies for managing introduced pests, development of improved techniques for mass production of host insects and biological control agents, storage techniques for natural enemies, superior strains of natural enemies and BIPM technologies for cotton, sugarcane, rice, tobacco, grain legumes, vegetables and fruit crops. Marked progress has also been made in the field of weed biocontrol. Through training programmes, workshops, seminars and sale of technologies our endeavor has been to popularize and spread the concept of biological control.

The thirteenth Annual Report is a compilation of the research achievements made by my scientist colleagues at PDBC and the AICRP centres for the period April 2005 to March 2006. We are confident that the information generated would be useful for researchers, administrators and policy makers, who are involved in the field of biological control. We welcome suggestions for improvement in the existing programmes and novel concepts for planning future research agenda and collaborative programmes.

I am extremely grateful to Dr. Mangala Rai, Secretary, DARE & Director General, ICAR, New Delhi, for his constant encouragement and guidance. The support extended by Dr. G. Kalloo, Deputy Director General (Crop Sciences & Horticulture), ICAR, New Delhi, is gratefully acknowledged. Our thanks are due to Dr. T.P. Rajendran, Assistant Director General (Plant Protection), ICAR, New Delhi, for his active involvement in planning the research programmes and for his guidance and support throughout the period of 2005-06. My sincere thanks are due to all project workers at Project Directorate of Biological Control and different co-ordinating centres of AICRP for successfully completing the committed research programmes. I place on record my sincere thanks to the Vice-chancellors, Directors of Research of SAU-based centres and Directors of ICAR Institute-based centres for providing the necessary facilities.

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

2. निष्पादित सारांश

वर्ष २००५-०६ के दौरान, जैविक नियंत्रण परियोजना निदेशालय (जै.नि.प.नि.) बेंगलोर, १० राज्य कृषि विश्वविद्यालयों और भारतीय कृषि अनुसंधान परिषद आधारित ६ केन्द्रों के साथ-साथ कई निजी स्वैच्छिक संगठनों के केंद्रों पर प्राथमिक और प्रायोगिक दोनो प्रकार के गहन कार्यक्रमों के अंतर्गत अखिल भारतीय समन्वित अनुसंधान परियोजना के तहत जैविक नियंत्रण पर, फसलों के हानिकारक कीटों, रोगों और खरपतवारों के पर्यावरणीय प्रबंधन के अंतर्गत जैव-नियंत्रण प्रौद्योगिकियों का विकास किया गया। फसलों में उत्पन्न होने वोले नए-नए पीडकों की समस्याओं, जैसे-गन्ने के वूली (रुईदार) माहूँ, *बी टी* कपास की फसल के चूषक कीटों का पर्यावरणीय प्रबन्धन तथा जैविक खेती में जैविक नियंत्रण का समेकित प्रबंधन कार्यक्रम अपनाया जा रहा है। अधिकांशतः परीक्षणों को वर्ष २००५-०६ के अंतर्गत आने वाली तकनीकी कार्यक्रम के तहत सफलतापूर्वक कार्यन्वित किया गया।

प्राथमिक अनुसंधान

जैविक नियंत्रण परियोजना निदेशालय, बेंगलोर

जीव वर्गीकरण

दो वंशों *नेडीना* और *नीओजोवरेविआ* का क्रमशः *प्रोटोथिआ* और *फेरोस्किम्नस* का पर्याय पाया गया। *नीओजोवरेविआ नेईडा* का *फेरोस्किम्नस फ्लेकसिबिल्स* का पर्याय पाया गया। *स्टाइकोलोटिस क्वाड्रीसिग्नेटा* नामक नई प्रजाति पाई गई और *एस. गोमी* से उत्कृष्ट पाया गया।

साइक्लोपेल्टा सिसिफोलिया को (पेंटाटोमाइडे) से *लाइफोसिया एग्साइसा* (सिलिन्ड्रोमाइनी) और *टोल्यूम्निआ* स्पे. (पेंटाटोमाइडे) से *सिलिन्ड्रोमिआ रूफिपेस* अभिलेखित किए गए। अरहर और लोबिया की फसल पर *हेलीकोवर्पा आर्मिजेरा* पर *कार्सेलिआ इल्लोटा* द्वारा ११% और *गोनिओफ्थालमस हाली* द्वारा २% तक परजीवीकरण पाया गया। *काइलो पारटीलस* पर *स्टरमियाप्सिस इनफेरेन्स* द्वारा ५% तक परजीवीकरण पाया गया।

प्राकृतिक शत्रु कीटों का उपोदघात

स्माइक्रोनिक्स लुटूल्लेन्टस, नेफेस्पिस बाइकॉलर, गोनस्पिडियम नाइग्रीमेनस (= यूटिलिस), *क्राइसोकेरिस ओसिनिडिस, डेल्फास्टस ट्रिप्टस, टे. लेवीसेप्स* और *टे. यूलयेटी* को आयात करने के लिए पादप संरक्षण सलाहाकार, भारत सरकार द्वारा आयात करने का नवीनीकरण प्राप्त किया गया।

कृषि विज्ञान विश्वविद्यालय, बेंगलोर में *क्रोमोलीना ओडोरेटा* पर तना गाँठ मक्खी, *सेसीडोकेरिस कोनेक्सा* को छोडा गया और परिणाम एकदम अनुकूल पाए गए, तना गाँठ मक्खी छोडने से पौधे की वृद्धि काफी हद तक रुक गई। तना गाँठ मक्खी को जिस स्थान पर छोडा गया उसकी अगली पीढी उस क्षेत्र बिन्दु से उत्तर दिशा में २५ मीटर और दक्षिण, पूरब तथा पश्चिम दिशाओं में ५० मीटर तक की दूरी तक फैली पाई गई। नवम्बर २००५ के दौरान *माइकेलिआ* स्पे. पर *एनकार्सिआ गुएडेलोउपे* अत्यधिक परजीवीकरण (८३.३%) पाया गया। अमरूद और *केसिआ* स्पे. के वृक्षों पर क्रमशः नवम्बर के पहले और अन्तिम सप्ताह में ८०% से अधिक परजीवीकरण पाया गया।

पारस्परिक अध्ययन दर्शाते हैं कि *ट्राइकोग्रामा ब्रेसिके* और *ट्राइकोग्रामेटॉयडिआ बेक्ट्रे* को *कोरसेरा* के अंडें परजीवित कराए जाते हैं तो *ट्राइकोग्रामेटॉयडिआ बेक्ट्रे* द्वारा ५१.५% अंडे परजीवित पाए गए, जबकि *ट्रा. ब्रेसिके* द्वारा केवल ४८.५% अंडे परजीवित पाए गए।

प्राकृतिक शत्रु कीटों का पालन पोषण और मूल्यांकन

साइटोट्रोगा सेरेलेल्ला से ग्रसित धान की फसल पर जब *ब्लेप्टोस्टिथस पेलेसेन्स* के निम्फों को १:५ के अनुपात की दर से छोडा गया तब १, २, और ३ बार छोडने पर हानिकारक कीटों के निकलने की दर क्रमशः ११.१, ४.४ और १६.३% थी, जबकि *का. एक्जिगुअस* छोडने पर क्रमशः २.२, १.१ और ० प्रतिशत रही। ज्वार के भण्डार गृह से *जाइलोकोरिस फ्लेविपस* प्राप्त किया गया।

स्पोडोप्टेरा एक्जिगुआ कीट को अंडनिक्षेपण के लिए अधोस्तर के रूप में बटर पेपर और मोमीय कागज का प्रयोग करने पर पाया कि इस कीट ने इन अधोस्तरों पर क्रमशः ५३.६ और ४६.४ प्रतिशत अंडनिक्षेपण किया। पहले की अपेक्षा इस विधि को अपनाने पर अंडों के सेने की दर भी अत्यधिक (६७.८%) पाई गई।

केम्पोलेटिस क्लोरिडिए की क्षमता पर केरोमोन के प्रभाव का पिंजडे में किए गए अध्ययन से स्पष्ट हुआ कि उपचारित (*स्पो. लिट्यूरा* के ९ दिन आयु वाले लारवों को केरोमोन से उपचारित किया गया) समूहों का परजीवीकरण अत्यधिक (४०.२%) जबकि अनुपचारित समूहों का परजीवीकरण बहुत कम (२५%) रहा।

टेलीनोमस रेमस के विभिन्न आयु (३-५, ६-८ और ८-१० दिन वाले) के परजीवित अंडे वाले कार्डों को अलग-अलग अवधि के लिए १५±२° से.ग्रे. (६०±२% आपेक्षित आर्द्रता) पर संग्रहित किया गया। इस परीक्षण में पाया गया कि ६-८ दिन आयु वाले अंडों को १० दिन तक संग्रहित रखा जा सकता है और ५ से १० दिनों तक संग्रहण करने पर अंडों से कीट निकलने की दर क्रमशः ९५.४% और ८९.५% रही।

ओरिअस टेन्टेलिस और *ब्ले. पेलेसेन्स* परजीवी कीट, *कोरसेरा सीफेलानिका* तथा *हे. आर्मिजेरा* के परजीवीकृत अंडों की तुलना में अपरजीवीकृत अंडों को प्राथमिकता देते हैं।

माइक्रोमस इगोरोटस के परपोषी कीट विस्तार परीक्षण में पाया गया कि इसके लारवे माहूँ की ग्यारह जातियों पर जीवित रहे और माहूँ रहित सात जातियों पर जीवित नहीं रह पाए। *माइक्रोमस इगोरोटस* को जब *स्यूडोरेग्मा बेम्बूसिकोला* पर पाला गया तब अत्यधिक (७९९.९ अंडे/मादा) अण्डनिक्षेपण किया जबकि *सीरेटोवेक्यूना लेनिजेरा* पर पालने पर बहुत कम (५९०.२ अंडे/मादा) अंडनिक्षेपण पाया गया। लिंग अनुपात में हमेशा मादा कीट अधिक निकली अर्थात ६० प्रतिशत मादायें तथा ४० प्रतिशत नर निकले।

साइटोट्रोगा सीरीएलेल्ला पर क्रिप्टोलीमस मोन्ट्रयूजिएरी का अंडा, लारवा और प्यूपा काल का विस्तार क्रमशः ५.१० - ८.१२, १५.७ - २४.१२ और ७.५९ - १०२ दिन पाया गया। कीट का कुल औसत जीवन चक्र ३७.७८ से ३९.० दिनों का रहा। सर्वाधिक जनन क्षमता का औसत मक्का की फसल पर (१२९.६ अंडे/मादा), इसके बाद धान की फसल पर (११९.८६ अंडे/मादा) पाई गई। संशोधित प्रौढ़ अंड निक्षेपण पिंजडे में ७८.०८ प्रतिशत अंडे एकत्रित किए जा सके और यह पिंजडा चार दिनों तक प्रयोग में लाया जा सका। प्रौढ़ मीथ को एकत्र करने का एक नया उपकरण तैयार किया गया, इस उपकरण का यह लाभ है कि कीट पालने में कोई बाधा उत्पन्न नहीं होती और मीथ को अंडनिक्षेपण पिंजडे से सीधे ही पकडा जा सकता है जिससे कि पौढ़ कीट कम बाधित होते हैं।

गन्ने के वूली माहूँ, *डाइफा एफिडिवोरा* ने दो पूँछ वाली मीलीबग, *फेरीसिआ विरगेटा* कीट पर अपना जीवन चक्र पूर्ण किया।

गन्ने के पौधे की ऊपरी पत्तियों की अपेक्षा निचली पत्तियों पर अधिक वूली माहूँ एकत्र रहते हैं। जैसे-जैसे पौधा बढ़ता जाता है, माहूँ पौधे की ऊपरी पत्तियों पर जाकर समूहों में जाकर इकट्ठा हो जाते हैं। *स्यू. बेम्बूसिकोला* के सैनिक कीटों की संख्या का अनुपात अधिक (२२-२४ प्रतिशत) जबकि *सी. लेनिजेरा* के समूह में सैनिक कीटों की संख्या का अनुपात कम (१०-१२ प्रतिशत) पाया गया। इनके समूहों के आकार, घनत्व और प्राकृतिक शत्रु कीटों की संख्या का महत्वपूर्ण सुसंबंध पाया गया।

कीट विषाणुओं का प्रयोग

हे. आर्मिजेरा के दूसरे निरूप के लारवों के प्रति अनेक सम्मिश्रणों के साथ हे. एन पी वी का अलग-अलग मूल्यांकन करके उनकी दक्षता का परीक्षण किया जिसमें सूर्य परीक्षण मशीन (यह मशीन सूर्य के प्रकाश को उत्प्रेरित करती है) का उपयोग करते हैं। इसको ९० मिनट के लिए सूर्य के प्रकाश में ५०० डब्ल्यू/मी.^{2} की दर से प्रयोग करते हैं। चार सम्मिश्रणों (सोयाबीन का आटा {१०%}, टिनोपॉल {०.२%}, शीरा {५%}, सी एस के ई {१०%}) का विषाणुओं के साथ प्रयोग करने पर लारवों के लिए ८५% से अधिक घातक साबित हुआ, जबकि बोरिक एसिड {१.०%} और हल्दी {२%} के प्रयोग से लारवों के लिए क्रमशः ८२.२७ तथा ७४.४० प्रतिशत घातक साबित हुआ।

स्पो. लिट्यूरा के लारवों के प्रति बिना किसी सम्मिश्रण के किरणित *स्पो.लिट.* एन.पी.वी. के प्रयोग से लारवों के लिए केवल ३९.१६% जबकि टिनॉपाल (०.१%) मिलाकर प्रयोग करने से लारवों के लिए ८१.८% घातक साबित हुआ। *स्पो. लिट.* एन.पी.वी. के साथ सम्मिश्रण के रूप में सी एस के ई (६२.५%) + कॉर्न तेल (१.५%) + खांड २५% + टवीन (०.०४%) मिलाकर प्रयोग करना अत्यन्त प्रभावी और घातकता भी अत्यधिक (९५.२३%) बढ़ी।

कीट कवकीय रोगजनक

ब्यूवेरिआ बेसिआना कवक के उत्पादन माध्यम के रूप में ०.२% कोलॉयडल काइटिन या २% शुद्ध काइटिन को टॉल्क नियमन या इस प्रकार उपचारित संयोजनों को कमरे के तापमान (१७ - ३२° से.ग्रे.) पर ८ महीनों तक सुरक्षित रखा जा सकता है। *नोम्युरिआ रिलेई* के संदर्भ में उत्पादन के माध्यम में ०.२% कोलॉयडल काइटिन या २% शुद्ध काइटिन को टॉल्क नियमन में मिलाने से *नो. रिलेई* की सी एफ यू को कम (क्रमशः २९.५ x १०^6/ग्राम और २४.७ x १०^6/ग्राम) कर देता है, जबकि अन्य सामान्य माध्यम का टॉल्क नियमन उत्पाद से सी एफ यू अधिक (३७.८ x १०^6/ग्राम) होती है।

बेसीलस थ्यूरिजिएन्सिस के देशी विभेदों का पृथककरण और विशेषताएँ

बीटी पृथककरण से २७ पृथककरणों को पृथक किया गया और उनमें से १५ पृथककरणों में क्रिस्टल पाए गए। छत्तीसगढ़ राज्य के वनों से २१ मृदा प्रतिदर्श (नमूने) एकत्र किए गए और *बी टी* विशिष्ट माध्य पर सात *बी टी* पृथकों का शुद्धिकरण किया गया। *प्लूटेला जाइलोस्टेला* के प्रति *बी टी* के चार पृथकों की एल सी$_{५०}$ मूल्यों का आकलन किया गया और उसकी तुलना में मानकीकृत एच डी-१ विभेद के साथ तुलना की गई। *बी टी* ४ (लॉग ५.७३ बीजाणु/मि.ली.) में सर्वाधिक विषैलापन जबकि *बी टी* ८ (लॉग ७.९७ बीजाणु/मि.ली.) न्यूनतम विषैलापन पाया गया।

अंतः पादपी जीवाणुओं का पृथककरण

सर्वप्रथम चने के स्वस्थ पौधों से अंतः पादपी जीवाणुओं को पृथक किया गया और उनकी पहचान *बेसिलस मेगाटेरियम* (एम टी सी सी ६५३३), *बेसिलस* स्पे. (एम टी सी सी ६५३५), *बेसिलेन्स* (यू ए एस ६५३४), *एर्विनिआ हर्बिकोला* (यू ए एस ६७२०) और *एन्टेरोबेक्टर आगलोमेरॉन्स* (एम टी सी ६५३६) के रूप में की गई। *फ्यूजेरिअम ऑक्सीपोरम* प्रजाति *लाइकोपर्सिकाई* के प्रति जिन टमाटर के स्वस्थ पौधों ने रोगप्रतिरोधिता दर्शाई, उन टमाटर के स्वस्थ पौधों से दो रहाइजोस्फियरों को पृथक किया गया। पृथकों का शुद्धिकरण किया गया और उनकी पहचान *स्यूडोमोनॉज एरूगिनोसा* (एम टी सी सी ७५१२) और *क्रिप्टोमोकस एल्बिडस* (एम टी सी सी ७४३६) के रूप में की गई।

ग्रीन हाऊस में, बे. *मेगाटेरिअम* से उपचारित पौधों ने ४११६.६७ तक का अत्यधिक वर्जस्व दर्शाया। अंतः पादपी जीवाणुओं के साथ बीज जीवाणुवीयकरण के परिणामस्वरूप ४ दिनों में ही फिनॉल अवयवों की मात्रा बहुत अधिक बढी और बे. *मेगाटेरिअम* के साथ प्रयोग करने से फिनॉल की मात्रा अत्यधिक (५०५ ug/ग्राम) पाई गई, जबकि अनुपचारित विधि के प्रयोग करने में बहुत कम (२९० ug/ग्राम) पाई गई।

पादप भक्षी कीटों के जैविक नियंत्रण के लिए रोगाणु

जीव-क्षमता अध्ययन में *हिर्सुटेला थोम्पसोनाई* और *हि. थोम्पसोनाई* जाति *साइनेमेटोसा* पिलेट्स को निर्जर्मिकृत पानी के साथ कमरे के तापमान पर और फ्रीज में रखने पर देखा गया कि *हिर्सुटेला थोम्पसोनाई* और *हि. थोम्पसोनाई* जाति *साइनेमेटोसा* पिलेट्स फ्रीज के अन्दर १३ महीनों तक संग्रहित करने पर भी उनकी जीव क्षमता बनी रही और वृद्धि दर क्रमशः ०.८९ मि.मी./दिन और ०.९६ मि.मी./दिन पाई गई।

हि. थोम्पसोनाई जाति *साइनेमेटोसा* (एम एफ (ए जी) २७ से ३२) के छः पृथकों को पृथक किया गया और १० विभिन्न माध्यमों पर गुणित किया गया। *हि. थोम्पसोनाई* जाति *साइनेमेटोसा* का त्रिज्यात्मक विकास और सिनेमेटा का उत्पादन जई-मील-अगार पर उत्कृष्ट पाया गया। एम एफ (ए जी) ३२ का सर्वाधिक विकास (६४.३३ मि.मी.) पाया गया और इसकी विकास दर १.९५ मि.मी. प्रतिदिन देखी गई।

हि. थोम्पसोनाई के जैव मात्रा विशेषताओं के विभिन्न अधोस्तर सक्रियता के प्रभाव परीक्षण में दर्शाया कि, सी एफ यू संख्या, पिलेट संख्या, गीले तथा शुष्क भार के आधार पर "टवीन" ८० सर्वोत्तम पाया गया, किन्तु पिलेट्स के आकार कुछ खास नहीं पाए गए। अनुपचारित (असंशोधित विधि) की अपेक्षा "टवीन" ८० सी एफ यू की संख्या २.४ गुणा अधिक पाई गई।

हि. थोम्पसोनाई के बहोत्पादन के लिए प्रायः आलू डेक्सट्रोज ब्रोथ (पी डी बी) की जगह टमाटर के द्रवीय माध्यम आधारित नए माध्यम का विकास किया गया।

हि. थोम्पसोनाई के बहोत्पादन के लिए प्रायः आलू डेक्सट्रोज ब्रोथ (पी डी बी) की जगह टमाटर के द्रवीय माध्यम आधारित नए माध्यम का विकास किया गया।

फोलिक अम्ल की २०० μg/लीटर की सान्द्रता के प्रयोग से *हि. थोम्पसोनाई* में सी एफ यू की संख्या अत्यधिक और २.९ गुणा अधिक विकास पाया गया, इसके बाद १०० μg/ लीटर सांद्रता से २.६ गुणा विकास पाया गया जो कि अनुपचारित विधि की अपेक्षा बहुत अधिक था। बायोटिन को कोलॉयडल उत्पादन बढाने (७.५ μg/लीटर के लिए सक्षण पाया गया।

हि. थोम्पसोनाई के बीजाणुक जननावस्था संवर्धन से *टेट्रानीकस युर्टीसी* के अंडों पर प्रभाव पडा और अंडों का सेना भी कम (६४.६%) पाया गया। इसका *टेट्रानीकस युर्टीसी* के निम्फों पर भी विषैला प्रभाव देखा गया। एक प्रौढ़ मादा माइट इस रिसन से उपचारित पत्ती पर सात दिनों तक भक्षण करते हुए केवल ३०.७ अंडे देती है जबकि अनुपचारित पत्ती पर सात दिनों की अवधि तक भक्षण करते हुए ५१ अंडे देती है।

भिंडी की फसल पर *हि. थोम्पसोनाई* के साथ कार्बेक्सि मिथाईल सेलूलाज (सी एम सी) और अकेशिआ गोंद मिलाकर जब मूल्यांकन किया गया तो पाया कि सी एम सी का पहला और दूसरा छिडकाव करने पर माइटों के लिए क्रमशः ९३.५ और १५.३% सर्वाधिक घातक पाया गया।

कवक प्रतिरोधी

ट्राइकोडर्मा विरिडे

स्कलेरोशियम रोल्फसाई और फ्यूजेरियम सिसेरी के प्रति *ट्राइकोडर्मा विरिडे* के पृथकों (२७ पृथक) की जाँच की गई, उनमें से टी वी २, टी वी १२, टी वी, २१, टी वी २३, टी वी २५, टी वी ३४ और टी वी ३५ को *स्कलेरोशियम रोल्फसाई* के प्रति सर्वोत्तम पाया गया।

दोहरी प्लेट अध्ययन पर *फ्यू. सिसेरी* के प्रति टी वी ४ और टी वी १२ उत्कृष्ट पाए गए। कोलॉयडल काइटिन और *स्क. रोल्फसाई* की कोशिका भित्ति की संशोधित माधयम के प्रयोग से टी वी ४, टी वी ८ और टी वी १० पृथकों की वृद्धि ठोस माध्यम में बहुत तेजी से हुई और द्रवीय माध्यम पर टी वी ३२, टी वी ३५, टी वी ३६ और टी वी २९ पृथकों की वृद्धि अत्यधिक हुई। टी वी ३, टी वी ८, टी वी १०, टी वी २३, टी वी २५, टी वी २८, टी वी ३० और टी वी ३२ पृथकों की एक्सोकाइटिनेज क्रिया अत्यधिक हुई जबकि टी वी ३, टी वी १६ और टी वी २२ पृथकों की एंडोकाइटिनेज क्रिया अत्यधिक हुई।

ट्राइकोडर्मा विरेन्स

एस. रोल्फसाई के प्रति *ट्रा. विरेन्स* के ६ विभेद प्रभावी पाए गए। *ट्रा. विरेन्स* (टी वी एस ४, टी वी एस - आई टी सी सी, टी वी एस - सी पी सी आर आई और टी सी एस १२) के द्रवीय संवर्धन को जब कोलॉयडल काइटिन पर विकसित किया तब एक्सोकाइटिनेज क्रिया अत्यधिक पाई गई।

ट्राइकोडर्मा हरजिएनम

दोहरे संवर्धन में *फाइटोफ्थोरा पेरासिटिका* जाति *निकोटिनिए* के प्रति *ट्रा. हरजिएनम* के अट्ठाईस पृथकों की प्रतिरोधी क्षमता का परीक्षण किया गया। *फाइटोफ्थोरा पेरासिटिका* जाति *निकोटिनिए* को नियंत्रित करने के लिए पृथक टी एच ९ ने सर्वाधिक प्रभावित किया, इसके बाद टी एच-५, टी एच, डी टी एच-७, टी एच-१, टी एच-२, टी एच-३, टी एच-८, टी एच-७, टी एच-२१, टी एच - आई टी सी सी, टी एच १२ और टी एच - सी पी सी आर आई पृथक प्रभावी पाए गए।

ट्रा. हरजिएनम के संयोजन में काइटिन मिलाने पर सी एफ यू की संख्या संयोजन में ६ महीनों तक बनी रही जबकि अनुपचारित विधि में ४ महीनों के बाद ही सी एफ यू की संख्या संस्तुति किए गए स्तर ($2x10^{6}$) से कम पाई गई।

ट्रा. विरिडे के संयोजन में कोलॉयडल काइटिन को ०१ और ०.२ प्रतिशत मिलाने पर सी एफ यू की संख्या बढाने में सहायता मिलती है। कोलॉयडल काइटिन मिलाने से २-३ महीनों के लिए शैल्फ-लाईफ बढ जाती है।

संयोजन में ३ और ६% ग्लिसरोल की मात्रा मिलाने से संयोजनों में सी एफ यू की संख्या ८ महीनों तक बढी पाई गई। *ट्रा. विरिडे* में भी जब उत्पादन माध्यम में ३-६% ग्लिसरोल सांद्रता मिलाई गई तब सी एफ यू की संख्या ७-८ महीनों तक अधिकतम रखने में सफलता पाई गई।

अनुपचारित की अपेक्षा ताप उपचारित बायोमास के संयोजन की शैल्फ-लाईफ एवं सी एफ यू की संख्या ६ महीनों तक अत्यधिक पाई गई।

कीट रोगाण्विक सूत्रकृमि

वाउट्स माध्यम में संपूरक के रूप में केसीन-पेप्टोन (माध्यम का ६२-८९ लाख प्रति ग्राम) मिलाने पर इस माध्यम पर *स्टेइनर्नेमा कार्पोकेपसे* की वृद्धि अत्यधिक पाई गई। *स्टे. अबासी* और *स्टेइनर्नेमा कार्पोकेपसे* के द्वारा *हे. आर्मिजेरा* लारवों के १२ घन्टों में क्रमशः ५० और १२५ आई जे/लारवा घातक साबित हुए। *हेटेरेरहब्डिटिज इन्डिका* और *हे. बेक्टेरिओफोरा* २४ घंटों में घातक सिद्ध हुए। *हे. आर्मिजेरा* के प्रति *स्टे. अबासी* एल डी$_{५०}$ से भी अधिक प्रभावी पाया गया इसके बाद *स्टेइनर्नेमा कार्पोकेपसे, हेटेरेरहब्डिटिज इन्डिका* और *हे. बेक्टेरिओफोरा* प्रभावी पाए गए। प्रयोगशाला में ये सूत्रकृमि ग्लिसरीन और अरण्डी के तेल में ४५ दिनों तक जीवित रहे और उनके रोगाणुवीय क्षमता पर कोई बुरा प्रभाव नहीं पडा। *स्टेइनर्नेमा कार्पोकेपसे* और *हे. बेक्टेरिओफोरा* की सोडियम सल्फेट (०.२५-१%) ने अल्ट्रा वॉयलेट संरक्षक के रूप में सुरक्षा करता है। *स्टेइनर्नेमा कार्पोकेपसे* आई जे ४० x $१०^{६}$/१०० मि.ली. की दर से गोंद आधारित जैल संयोजन को संग्रहण और परिवहन के लिए अनुकूल पाया गया और ३०° से.ग्रे. तापक्रम पर ३० दिनों तक जीव-क्षमता भी बनी रही। शिमोगा के तम्बाकू उगाए जाने वाले क्षेत्रों में *हे. इन्डिका* की टॉल्क ५ बिलियन/हे. की दर से प्रयोग करने पर उसने *होलोट्रिशिआ* को सफलता पूर्वक नियंत्रित किया और प्रतिरोपण स्थापन बढा एवं स्वस्थ पत्तियों की संख्या बढी पाई गई।

पादप परजीवी सूत्रकृमियों का जैविक नियंत्रण

पोकोनिआ क्लेमॉयडोस्पोरिआ (पी डी बी सी पी सी ५६) के मूल पृथक *बीटा* - ट्यूबुलिन आनुवांशिक स्रोत (२७० बी पी) को व्यवस्थित क्रम में अभिलेखित करके एन सी बी आई जीन बैंक, मैरीलैन्ड (क्रम संख्या-डी क्यू ४१७६०३) में संग्रहित किया गया।

बैंगन और कपास के गमलों में उगाए गए पौधों में भेड की मिंगनी (मल) और वर्मिकम्पोस्ट को खाद के रुप में प्रयोग करने से *आर्थ्रोबोट्रिस ओलिगोस्पोरा* ने धागाकार सूत्रकृमियों और मूलग्रंथियों के प्रति अपनी जैव दक्षता रुप में प्रदर्शित की है।

आर्थ्रोबोट्रिस ओलिगोस्पोरा के बहोत्पादन के लिए प्राकृतिक स्त्रोतों से ठोस, द्रवीय और द्विस्तरीय माध्यमों की पहचान की गई और उनके उत्पादन चक्र तथा उपज बढाने वाली दशाओं का मानकीकरण किया गया।

स्यूडोमेनाज फ्लूरोसेन्स संयोजनों के सिस्टेमिक प्रतिरोधी अध्ययनों से प्रदर्शित होता है कि अनुपचारित टमाटर के पौधों की अपेक्षा उपचारित टमाटर के पौधों के मूलग्रन्थि सूत्रकृमि नियंत्रण के लिए संयोजन प्रभावी है और इनके प्रयोग करने से पौधों का अच्छा विकास (पौधे की ऊँचाई, नए वानस्पतिक भागों का भार एवं शुष्क भार की दशाओं में) अत्यधिक प्रभावी पाया गया।

मई-जून माह के दौरान मिट्टी का ताप बढाने के लिए २९ दिनों तक प्लास्टिक शीट को मल्च के रूप में प्रयोग करके टमाटर के बीज नर्सरी में बोने के पहले *पो. क्लेमॉयडोस्पोरिआ* (२X१०^{१०} बीजाणु/ मी.^{२}) तथा नीम की खली (१ कि.ग्रा./ मी.^{२}) मिट्टी में अचछी प्रकार मिलाने के दो महीनों के बाद अधिकतम कवकीय सी एफ यू की संख्या प्रति ग्राम पाई गई और जडों का फैलाव भी अच्छा पाया गया जबकि बिना मल्चिंग करने से केवल कवक तथा नीम की खली का प्रयोग करने से इतने अच्छे परिणाम प्राप्त नहीं हुए।

पेसीलोमाइकस लिलेसिनस या *पो. क्लेमॉयडोस्पोरिआ* के संयोजन के ३० कि.ग्रा./हेक्टेअर के साथ वर्मिकम्पोस्ट को २०० कि.ग्रा./हे. की दर से गर्किन के बीजों को बोने से पहले खेत में बनी नालियों (Furrows) में डालने पर फसल बढने के ७५ दिनों के समय में मूलग्रन्थि सूत्रकृमि के ५४-७२% अंड समूह ग्रसित पाए गए, मिट्टी में सूत्रकृमि की संख्या में २२ से ३८% तक की कमी देखी गई और जड संक्रमण में ३८-६६% तक की कमी देखी गई।

प्राकृतिक शत्रु कीटों का व्यवहारिक अध्ययन

एक फर्न, *चीनोपोडियम* स्पे. और बेसिल पत्तियों *(ओसिमम सेंक्टम)* से वाष्पशील कार्बनिक यौगिकों को प्रपंचित, पृथक और उनकी पहचान की गई। फर्न की पत्तियों से अट्ठाईस यौगिकों की पहचान की गई।

माध्य एक्सेटस आनुपातिक सूची अध्ययन में पाया कि चार पादप वाष्पशीलों, जो कि पेन्टाकोसेन + हेप्टाकोसेन + आक्टोकेसेन के क्रमशः १ : ३ : १ : १ के अनुपात में ५०% सान्द्रता का मिश्रण परभक्षी कीट, *क्राइसोपर्ला कारनिआ* के ४ दिनों की आयू के प्रौढ़ों को बहुत ज्यादा आकर्षित करता है। मिथाईल सेलाईसिलेट को, परभक्षी कीटों की अनेक प्रजातियों को आकर्षित करने वाला पाया गया। कपास की फसल में पौधों पर २४ से ४८ घंटों तक का प्रयोग करने पर परभक्षी कीट, *क्राइसोपर्ला कारनिआ* ने अत्यधिक अंडे दिए।

संशोधित विभेदों का विकास और मूल्यांकन

परभक्षी कीट, *क्राइसोपर्ला कारनिआ* की कम तापमान (१८-२४° से.ग्रे.) सहने वाली विभेदों का विकास किया गया।

प्रयोगशाला दशाओं के अन्तर्गत *ट्रा. किलोनिस* को ३० पीढ़ियों तक पालने के बाद कम तापमान (१८-२४° से.ग्रे.) सहने वाली विकसित की गई। *ट्रा. किलोनिस* के कम तापमान सहिष्णु कवभेदों के विकास, परपोषी कीट ढुँढने की क्षमता और जैविक मापदण्डों के अध्ययन में पाया गया कि प्रयोगशाला में पाले गए विभेदों की तुलना पिंजडे में सामान्य तापक्रम पर पाले गए विभेदों से की गई। कम तापमान असहिष्णु विभेद द्वारा केवत १७.२% अंडे परजीवित पाए गए जबकि कम तापमान सहिष्णु विभेद द्वारा ५८ प्रतिशत अंडे परजीवित पाए गए।

पी सी आर और आर ए पी डी- पी सी के द्वारा *ट्राइकोग्रामा* स्पे. से डी एन ए पृथक करने की एक तकनीक का मानकीकरण किया गया। आई टी एस - १ और आई टी एस-२ प्राइमरों का क्रमशः ६०० बी पी और ५०० बी पी पर परीक्षण किया गया। आई टी एस-२ रीजन पर ट्राइकोग्रामेटिड्स की सात प्रजातियों / विभेदों को श्रेणीगत करके उन्हें जीन बैंक में {एक्सेशन संख्या डी क्यू २२०७०३ *(ट्राइकोग्रामा किलोनिस)*, डी क्यू ३१४६११ *(ट्राइकोग्रामा ब्रेसिके)*, डी क्यु ३८१२८१ *(ट्राइकोग्रामा ब्रेसिलिएन्सि)*, डी क्यू ३८१२८० *(ट्राइकोग्रामा इवानेसेन्स)*, डी क्यू ३८१२७९ *(ट्राइकोग्रामा मवान्जाई)*, डी क्यू ३४४०४५ *(ट्राइकोग्रामा डेन्ड्रोलिमाई)* और डी क्यू ३४४०४४ *(ट्राइकोग्रामा एम्ब्रियोफेगम)* में संग्रहित किया गया।

टमाटर की फसल में, *ट्राइकोग्रामा किलोनिस* के बहु कीटनाशी सहिष्णु विभेद को छोडने पर *हे. आर्मिजेरा* के ३४.१% अंडों पर इन कीटों द्वारा परजीवीकरण पाया गया और यह परजीवीकरण, प्रयोगशाला में पाले गए विभेदों को प्लॉट में छोडने या किसान के खेत में प्राकृतिक परजीवीकरण की तुलना से कहीं अधिक पाया गया।

परजीवी कीटों और परभक्षी कीटों के लिए कृत्रिम आहार

आरियस टेन्टीलस की मादा कीट, सोयाबीन हाइड्रोलाइसेट और यीस्ट अर्क आधारित प्रयोगशाला में संशोधित किए गए कृत्रिम आहार पर १० दिनों तक जीवीत और सामान्य रूप से अंडे (११ अंडे / मादा) देती रही।

पुणे से, बहुतायत में एकत्रित किए गए परभक्षी कीट, *क्रि. मोन्ट्रयूजिएरी* को गाय के यकृत आधारित कृत्रिम आहार पर पाला गया और उसकी तुलना पी डी बी सी की प्रयोगशाला में पल रहे परभक्षी कीट, *क्रि. मोन्ट्रयूजिएरी* से की गई। इनको जब कृत्रिम आहार पर पाला गया तो इन दोनों के संवर्धनों के लारवा काल, प्यूपा काल, प्यूपों के बनने (प्रतिशत) और प्यूपों से प्रौढ़ निकलने (प्रतिशत) के बीच में कोई विशेष अन्तर नहीं पाया गया।

क्रा. कारनिआ को पालने के लिए, सूअर के यकृत पर आधरित कृत्रिम आहार की अपेक्षा गाय के यकृत आधारित कृत्रिम आहार सर्वोत्तम पाया गया।

क्राइसोपिड और कोक्सीनेलिड परभक्षी कीटों के डी एन ए निकालने विधि का मानकीकरण किया गया। *क्रा. कारनिआ* (६०० बी पी) और *क्रि. मोन्ट्रयूजिएरी* (६०० बी.पी), जो कि कृत्रिम आहार और प्राकृतिक आहार पर पले थे, पी सी आर एम्पिलिफिकेशन आई टी एस-२ रिजन्स में पाया गया कि उनमें आपस में काई भी अन्तर नहीं पाया गया।

परपोषी कीटों के लिए कृत्रिम आहार

ओपिसिना एरेनासेल्ला को पालने के लिए एक अर्द्धसंश्लेषित आहार तैयार किया गया जिसमें ताड की पत्तियों का पाउडर एवं वसा रहित सोया का प्रयोग किया गया। लारवा परजीवी कीट, *गोनिओजस निफेन्टिडिस* और प्यूपा परजीवी कीटों- *ब्रेकीमेरिआ नोसोटाई और ब्रे. निफेन्टिडिस* को कृत्रिम आहार पर सफलतापुर्वक बहुगुणन किया गया। किया गया। *स्पोडोप्टेरा एक्जिगुआ* को पालने के लिए एक अर्द्धसंश्लेषित आहार पैयार किया गया। पार्थेनियम खरपतवार की पत्तियों के अर्क से बने एक अर्द्धसंश्लेषित आहार पर *जाइगोग्रामा बाइकोलोराटा* को पाला गया।

सॉफ्टवेयर का विकास

एक सॉफ्टवेयर तैयार की गई जिसमें चार सब्जियों वाली फसलों - सेम, बैंगन, आलू और टमाटर में लगने वाले पीडकों के बारे में सूचना दी गई है। सूक्ष्मजीवी जैवकारकों के बारे में एक डाटा बेस सॉफ्टवेयर का विकास कार्य अभी प्रक्रिया में है। मैप इन्फो प्रोफेशनल (वर्जन ७.५) तैयार किया गया और "एरिस कक्ष" में लगाया गया है।

फसलों के हानिकारक कीटों का जैविक नियंत्रण

गन्ना

बेधक कीट

पी डी बीसी द्वारा *ट्राइकोग्रामा किलोनिस* के तापमान सहिष्णु विभेद को ५०,०००/ हेक्टेअर की दर से छोडने पर तना बेधक के नियंत्रण के लिए रासायनिक नियंत्रण के समान ही पाया गया और कीटों के ग्रसन में ४०-४३% तक की कमी करने में सफल पाया गया। इस विधि को अपनाने पर लागत और लाभ का अनुपात १:७.४ पाया गया जबकि रासायनिक विधि अपनाने पर लागत और लाभ का अनुपात केवल १:३.८ पाया गया। पंजाब में, दो चीनी मिलों के सहयोग से लगभग १४४० हेक्टेअर क्षेत्रफत पर किसानों के खेतों में, *ट्रा. किलोनिस* के प्रभावीपन का बडे पैमाने पर प्रदर्शन किया गया। जुलाई से अक्टूबर माह के दौरान ट्रा. किलोनिस को ५०,०००/ हेक्टेअर की दर से ७ से १० दिनों के अन्तराल पर छोडने पर पोरी बेधकों का ६६.७ % तक ग्रसन कम किया जा सका। (पंजाब कृषि विश्वविद्यालय, लुधियाना)

काइलो ट्यूमिडिकास्टेलिस के प्रति *ट्रा. किलोनिस* के क्षेत्रीय मूल्यांकन में स्पष्ट पाया गया कि जिन क्षेत्रों में परजीवी कीट छोडे गए थे उनमें हानिकारक कीटों का ग्रसन केवल २०% पाया गया जबकि उन क्षेत्रों में जिनमें परजीवी कीट नहीं छोडे गए थे उनमें हानिकारक कीटों का ग्रसन ४५% पाया गया तथा परजीवी कीट छोडे गए क्षेत्रों में पीडकों के अंडों की परजीवितता ३४% पाई गई, जबकि किसान द्वारा अपनाई गई विधि वाले क्षेत्रों में पीडकों के अंडों की परजीवितता केवल १२% पाई गई। जैविक नियंत्रण विधि अपनाए गए खेतों में उपज अधिक (७८ टन/ हेक्टेअर) प्राप्त हुई (असम कृषि विश्वविद्यालय, जोरहट)

वूली माहूँ

महाराष्ट्र राज्य के नौ कृषि- जलवायु क्षेत्रों में उगाए गए गन्ने के वूली (रूईदार) माहूँ से ग्रसित फसल क्षेत्रों में ग्रसन कम (९.१४%) पाया गया। परभक्षी कीटों, *एफिडिवोरा* और सिरफिडों की साख्या कम तथा माइक्रोमस इगोरोटस परभक्षी कीट की संख्या मध्यम / सामान्य पाई गई. किसानों द्वारा अपनाई जाने वाली शस्य क्रियाओं की तुलना में डाइफा एफिडिवोरा को १००० लारवे प्रति हेक्टेअर की दर से छोडने पर गन्ने के वूली माहूँ की संख्या को ४५ दिनों के अन्दर ही सफलतापूर्वक कम किया। *डाइफा एफिडिवोरा* का पूरा जीवन चक्र ५४.३ दिनों में पूर्ण हुआ। *डाइफा एफिडिवोरा* का बहोत्पादन बाँस से बने ढाँचे (५ X ४ X ४ मीटर) में छाया प्रदान करने वाले जालीदार(५० गेज वाली जाली) संरचनाओं में गन्ने की फसल (७ महीने की फसल) पर गन्ने के

वूली माहूँ को पाल कर किया गया, इस तकनीक को अपनाने से दो महीनों के अन्दर ही परभक्षी कीट के १२३० लारवे / प्यूपे प्रति छ्यादार संरचना से प्राप्त हुए। (महात्मा फुले कृषि विद्यापीठ, राहुरी)

तमिलनाडू में, जुलाई माह के दौरान वूली माहूँ का ग्रसन अत्यधिक और जुलाई से जनवरी माह तक यह ग्रसन कम होता गया। माहूँ के ग्रसन की सघनता मार्च, २००६ के दौरान अधिक देखी गई।

अधिक तापमाने और आपेक्षिक आर्द्रता का गन्ने के वूली माहूँ की संख्या पर कोई सहसंबंध नहीं दिखाई दिया जबकि कम तापमान और आपेक्षिक आर्द्रता का गन्ने के वूली माहूँ की संख्या पर सकारात्मक सहसंबंध दर्शाता है। वर्षा और हवा की गति का गन्ने के वूली माहूँ की संख्या का नकारात्मक सहसंबंध देखा गया। *डाइफा एफिडिवोरा* और *मा. इगोरोटस* की संख्या पर मौसम के मापदण्डों का कोई विशेष प्रभाव नहीं देखा गया। (तमिलनाडू कृषि विश्वविद्यालय, कोयम्बटूर)

डाइफा एफिडिवोरा और *मा. इगोरोटस* की संख्याओं (समूह) का छाया प्रदान करने वाले नेट हाऊस में परपोषी कीट *सी. लेनिजेरा* के ग्रसन की सघनता के ऊपर निर्भर पाई गई। *डाइफा* के कोकून औसतन ४.२ कोकून / पत्ती और *माइक्रोमस* की ग्रब्स औसतन ०.००७ ग्रब प्रति पत्ती पाई गई। डाइफा को क्षेत्र में छोडने के परिणामस्वरूप चार महीनों के बाद ९३.६-९७.२ प्रतिशत नियंत्रण पाया गया। विभिन्न सघनताओं पर दोनों ही परभक्षी कीटें में आपस में कोई प्रतिद्वन्द्वता नहीं देखी गई और बिना किसी प्रतिकूल प्रभाव के एक ही जगह पर पलते और बढ़ते रहे। (तमिलनाडू कृषि विश्वविद्यालय, कोयम्बटूर)

कोयम्बटूर में, अक्टूबर - जनवरी माह के दौरान गन्ने के वूली माहूँ और *डाइफा* की सक्रियता सामान्यतः अधिक पाई गई। पत्ती के छोटे टूकडे जिन पर माहूँ के समूह थे, पर *डा. एफिडिवोरा* को पालने वाली एक साधारण बहुगुणन संवर्धन तकनीक को प्रयोगशाला में अपनाया गया। *डा. एफिडिवोरा* को क्षेत्र में छोडने पर माहूँ कीट की सघनता कम और *डा.एफिडिवोरा* की संख्या अत्यधिक बढ़ी पाई गई। (गन्ना प्रजनन संस्थान, कोयम्बटूर)

हरियाणा में, अनेक चीनी मिलों वाले क्षेत्रों में मानसून के बाद किए गए सर्वेक्षणों के दौरान गन्ने के वूली माहूँ का ग्रसन नहीं पाया गया। (चौधरी चरण सिंह हरियाणा कृषि विश्वविद्यालय, हिसार)

असम से लाए गए *एनकार्सिआ फ्लेवोस्कूटेलम* परजीवी कीट को आन्ध्र प्रदेश के मेड़ाक तथा संगारेड्डी जिलों में उपनिवेशित करने के प्रयास में असफल रहे। (आचार्य एन जी रंगा कृषि विश्वविद्यालय, हैदराबाद)

आसाम के, बुरालिक्सन और गौलघाट क्षेत्र में गन्ने के वूली माहूँ की संख्या अधिकतम तापमान पर (सहसंबंध कारक r=०.०६२) और कम तापमान पर (सहसंबंध कारक r=०.७३४) अर्थात उच्च और निम्न तापमान के साथ सकारात्मक सहसंबंध दर्शाया। इसी प्रकार माइक्रोमस और सिरफिडों का भी उच्च और निम्न तापमान के साथ सकारात्मक सहसंबंध पाया गया जबकि *डा.एफिडिवोरा* ने उच्च तापमान के साथ सकारात्मक सहसंबंध (सहसंबंध कारक r=०.७०९) दर्शाया। (असम कृषि विश्वविद्यालय, जोरहट)

उच्च तापमान और गन्ने के वूली माहूँ की संख्या के बीच महत्वपूर्ण सकारात्मक सहसंबंध (सहसंबंध कारक r=०.०९०५) पाया गया। *डा. एफिडिवोरा* की संख्या के साथ माहूँ की संख्या के बीच महत्वपूर्ण नकारात्मक सहसंबंध कारक r=-०.८०२) पाया गया। गन्ने के वूली माहूँ के ग्रसन के कारण चीनी की मात्रा और गन्ने के भार में क्रमशः ९.९५ (सी ओ एस ७६७) से १९.८० (सी ओ एस ७६७) और १०.५६ (सी ओ एस ८४३६) से २०.४५ (सी ओ एस ७६७) प्रतिशत तक की कमी पाई गई। (भारतीय गन्ना अनुसंधान संस्थान, लखनऊ)

कपास

पंजाब राज्य के दो स्थानों पर *बी टी* कपास के जैव प्रबलित कीट प्रबंधन के अन्तर्गत परीक्षण किए गए और इसमें पाया गया कि बी टी रहित संकर प्रजातियों में कोई विशेष अन्तर दिखाई नहीं पडा, क्योंकि इनमें हानिकारक कीटों की संख्या कम थी। आश्रय प्रबंधन वाले क्षेत्रों में प्राकृतिक शत्रु कीटों की संख्या अत्यधिक (०.८२) इसके बाद जैव प्रबलित कीट प्रबंधन प्रक्रिया अपनाने पर प्राकृतिक शत्रु कीटों की संख्या (०.६८) और रासायनिक कीट प्रबंधन प्रक्रिया अपनाने पर प्राकृतिक शत्रु कीटों की संख्या बहुत कम (०.०६) पाई गई। सभी उपचारों के प्रयोग के दौरान चूसने वाले कीटों तथा गूलर सूंडियों की संख्या बहुत कम पाई गई। (पंजाब कृषि विश्वविद्यालय, लुधियाना) प्रबंधन तकनीक अपनाने पर चूसने वाले कीटों की संख्या तुलनात्मक रूप में बहुत कम पाई गई और इसका मुख्य कारण यह पाया गया कि जैव प्रबलित कीट प्रबंधन तकनीक में प्राकृतिक शत्रु कीट बहुत सक्रिय थे । *हे. आर्मिजेरा* के संदर्भ में बी टी रहित कपास क्षेत्रों की अपेक्षा बी टी कपास ने जैव प्रबलित कीत प्रबंधन और किसानों द्वारा अपनाई जाने वाली प्रक्रियाओं से उत्कृष्ट परिणाम दिखाए। (आचार्य एन जी रंगा कृषि विश्वविद्यालय, हैदराबाद)

जैव प्रबलित कीज प्रबंधन के अन्तर्गत, *बी टी* कपास में *हे. आर्मिजेरा और इरिआस विटेल्ला* की संख्या कम, गूलरों की हानि कम और उपज अत्यधिक प्राप्त हुई। किसानों द्वारा अपनाई जाने वाली शस्य प्रक्रियाओं की अपेक्षा जैव प्रबलित कीट प्रबंधन तकनीकें अपनाने पर प्राकृतिक शत्रु कीटों की सेख्या अत्यधिक प्राप्त हुई। (तमिलनाडू कृषि विश्वविद्यालय, कोयम्बटूर)

बी टी कपास के साथ वर्तमान काल में की जाने वाली अन्य शस्य प्रक्रियाओं के साथ मिलकर प्रयोग करने से माहूँ, फुदकों, थ्रिप्स और सफेद मक्खियों को प्रभावपूर्ण ढंग से नियंत्रित किया गया और अत्यधिक उपज प्राप्त हुई। *बी टी* कपास क्षेत्रों में जैव प्रवलित कीट प्रबंधन प्रक्रिया अपनाने पर परभक्षी कीटों की अत्यधिक प्राप्त हुई। (महात्मा फूले कृषि विद्यापीठ, राहुरी)

अन्य सभी उपचारों की तुलना *में बी टी* कपास + जैव प्रबंधन कीट प्रबंधन तकनीक अपनाने पर *इरिआस विटेल्ला* और *पेक्टिनोफोरा गोसिपिएल्ला* द्वारा कली और गुलरों की क्षति कम, रूई के रेशों क्षति कम हुई एवं चुसने वाने कीटों की संख्या बहुत कम पाई गई तथा कपास के बीजों की उपज अत्यधिक प्राप्त हुई। रासायनिक कीटनाशकों के प्रयोग वाली दो प्रक्रियाओं से प्रतिकूल प्रभाव दिखाई पडे और उनकी तुलना में *बी टी* कपास + जैव प्रक्रियाएँ अपनाने पर अनेक प्राकृतिक शत्रु कीटों की संख्या अत्यधिक पाई गई। (असम कृषि विश्वविद्यालय, जोरहट)

तम्बाकू

अकेले तम्बाकू की फसल लेने की अपेक्षा तम्बाकू को प्रपंची फसलों के साथ उगाने *पर हे. आर्मिजेरा* और *स्पो. लिट्यूरा* के अंडों का परजीवीकरण क्रमशः १.१३ गुणा अधिक पाया गया। यदि तम्बाकू को प्रपंची फसलों के साथ उगाया जाता है तो हानिकारक कीटों द्वारा होले वाली क्षति भी बहुत कम हुई। *स्पो. एक्जिगुआ* द्वारा पत्तियों को होने वाली क्षति को रोकने के लिए *नो. रिलेई, ब्यू. बेसिआना और वे.थ्यू. कुर्सटेकी* सभी एक समान प्रभावी पाए गए। प्रपंची फसलों के रूप में गेंदा और अरण्डी की फसलें क्रमशः *हे. आर्मिजेरा* और *स्पो. लिट्यूरा* को नियंत्रित करने के लिए प्रभावकारी पाई गई। (केन्द्रीय तम्बाकू अनुसंधान संस्थान, राजमुन्द्रही)

दलहनी फसलें

प्रयोगशाला में नियंत्रित दशाओं के अन्तर्गत *बी टी* जैव क्षमता परीक्षण में *बी टी* द्वारा उपचारित *हे. आर्मिजेरा* के लारवों के लिए यह ५३.२% घातक पाई गई। क्षेत्रीय दशाओं में २.० कि.ग्रा./ हे. की दर से प्रयोग करने पर लारवों की संख्या घटाने और ग्रसन की दर को करने में उत्कृष्ट पाया गया। (आचार्य एन जी रंगा कृषि विश्वविद्यालय, हैदराबाद)

प्रयोगशाला में अरहर की फली बेधक, *हे. आर्मिजेरा* के प्रति *बी टी* अत्यधिक घातक पाई गई। क्षेत्रीय दशाओं में किए गए अध्ययन में, *बी टी* का २.० कि.ग्रा./ हे. और नीम की खली का १.० किग्रा./ हे. की दर से प्रयोग करना उत्कृष्ट पाया गया तथा जब फलियों की उपच ली गई तो छिडकाव के ५ और ७ दिनों के बाद क्रमशः हे. आर्मिजेरा और मेरुका टेस्टूलेलिस की संख्या एक समान रूप से कम कर पाए। (असम कृषि विश्वविद्यालय, जोरहट)

धान

धान उगाने की जैविक खेती की तुलना रासायनिक विधि से की गई। धान के तना वेधक के अध्ययन में पाया गया कि सामान्यतः जिस विधि से धान उगाते हैं उनमें डेड हर्ट लक्षण बहुतायत में दिखाई देने हैं। सामान्यतः विधि से उगाए धान और जैविक खेती विधि रूप से उगाए धान के दानों की उपज एक समान पाई गई। खरीफ और रबी मौसम के दौरान सामान्यतः विधि से उगाए गए धान की अपेक्षा जैविक खेती विधि रूप से उगाए धान की फसल में प्राकृतिक शत्रु कीटें जैसे मकडी और कोक्सीनेलिडों की संख्या बहुत अधिक पाई गई। (केरल कृषि विश्वविद्यालय, त्रिसूर)

जैविक खेती विधि अपनाने पर धान के तना बेधकों (४.३%) और सफेद बालियों की संख्या कम (५.३%) पाई गई, जबकि किसानों द्वारा अपनाई जाने वाले क्षेत्रों में धान के तना बेधकों (१०.८%) और सफेद बालियों की संख्या अधिक (११.०%) पाई गई। किसानों द्वारा अपनाई जाने वाली प्रक्रियाओं में पत्ती मोडक कीट का प्रकोप अधिक (७.४%) जबकि जैविक खेती विधि अपनाने पर पत्ती मोडक कीट का प्रकोप कम (३.०%) पाया गया। जौविक खेती विधि अपनाने पर उपज अधिकतम (३६०२ कि.ग्रा./ हे.), जबकि किसानों द्वारा अपनाई जाने वाली प्रक्रियाओं में उपज न्यूनतम (२७०६ कि.ग्रा./ हे.), प्राप्त हुई। लागतः लाभ अनुपात के विश्लेषण में पाया गया कि जैविक खेती विधि अपनाने पर अधिकतम लाभ प्राप्त होना है। (असम कृषि विश्वविद्यालय, जोरहट)

पूरे निरीक्षण के दौरान, धान के पत्ती मोडक कीट, केस सूँडी, स्किपर बालों वाली सूँडी आदि हानिकारक कीटों की संख्या को कम करने के लिए बी टी संयोजनों की तीन मात्राओं (२, १.५ और १.० कि.ग्रा/ हे.), की दर से दो छिडकाव एक समान प्रभावकारी पाए गए। खरीफ और रबी दोनों मौसम में इसी प्रकार के परिणाम प्राप्त हुए। (केरल कृषि विश्वविद्यालय, त्रिसूर)

तना बेधकों और पत्ती मोडक कीटों की संख्या को कम करने में *बी टी* की सभी मात्रा के प्रयोग प्रभावकारी पाए गए।(असम कृषि विश्वविद्यालय, जोरहट)

मोटे और बासमती धान के पत्ती मोडक कीटों और तना बेधकों के नियंत्रण करने के लिए *बी टी* को २.० कि.ग्रा./ हे. की दर से प्रयोग करने पर अत्यन्त प्रभावकारी पाया गया। धान की जैविक खेती में पौध रोपण के ३० दिनों के बाद *ट्रा. किलोनिस* और *ट्रा.जेपोनिकम* को प्रत्येक बार १,००.०००/हे. की दर से सात बार प्रयोग करने पर पत्ती मोडक कीट को नियंत्रित करने के लिए प्रभावी पाया गया। (पंजाब कृषि विश्वविद्यालय, लुधियाना)

तिलहन

प्रयोगशाला में किए गए जाँच परीक्षणों में पाया गया कि सरसों की आरा मक्खी सभी कीट रोगाणुओं के प्रति विभिन्न दरों के साथ न्यूनतम एल सी$_{50}$ मात्रा *बी टी* (डी ओ आर विभेद)(०.९४८ ग्राम/ली.) के लिए न्यूनतम, इसके बाद बायोलेप (व्यवसायिक *बी टी* संयोजन) और मे. एनाइसोप्लिए के लिए अधिकतम सुग्राहा पाया गया। (असम कृषि विश्वविद्यालय, जोरहट)

क्षेत्रीय दशाओं में बी टी को २.० किग्रा/हे. की दर से उपचारित करने के ९० दिनों के बाद सरसों की आरा मक्खी का सफलता पूर्वक नियंत्रण किया गया। (असम कृषि विश्वविद्यालय, जोरहट)

नारियल

केरल के समुद्र के किनारे, वातनपल्ली क्षेत्र में पिछले दो वर्षे से *ओपिसिना एरेनोसेल्ला* के प्रति *ट्राइकोग्रामा एम्ब्रियोफेगम, गोनिआजस निफेन्टिडिस और कार्डिस्टेथस एक्जिगुअस* को छोडने पर प्रभावकारी पाया गया। प्रौढ कीट को ओरीक्टस बेक्युलो वायरस से उपचारित करके एक हेक्टेअर क्षेत्रफल में छोडा गया और खाद के गड्ढों को *मे. एनाईसोप्लिए* द्वारा उपचारित किया गया। एक महीने के बाद, नारियल के वृक्षों पर नया ग्रसन कम पाया गया। खाद के गड्ढों में ग्रब्जों के ऊपर *मेटारहाइजियम* का संक्रमण १००% पाया गया। (केरल कृषि विश्वविद्यालय, त्रिसूर)

ऊष्ण कटिबंधीय फल फसलें

अमरूद की सर्पिलाकार सफेद मक्खी के प्रति *एनकार्सिआ गुआडेलोऊपे* को छोडने पर परजीवीकरण, जून (५६.२%) से अगस्त (९६.३%) तक पाया गया और सफेद मक्खी की संख्या को न्यूनतम स्तर तक सीमित रखा गया।

कर्नाटक में किसानों के खेतों में, अंगुर की बेल के मीलीबगों के प्रति *क्रिप्टोलीमस मोन्ट्र्यूजिएरी* और अमरूद की सर्पिलाकार सफेद मक्खी के प्रति *एनकार्सिआ गुअडेलोऊपे* को छोडने पर प्रभावी नियंत्रण पाया गया। पोमेलो के मीलीबगों के प्रति *क्रिप्टोलीमस मोन्ट्रूजिएरी* को छोडना अत्यंत प्रभावी पाया गया। शरीफा फल वृक्ष पर *क्रिप्टोलीमस मोन्ट्रूजिएरी* छोडने से वृक्षों में ग्रसन कम, इसका माध्य ३६.८ और फलों का ग्रसन १८.९% तक कम पाया गया।

चीकू के वृक्षों पर जुलाई माह में, हरे शल्क कीट, *कोकस विरिडिस* की संख्या अत्यधिक (११.८ शल्क प्रति पत्ती) और मुख्य परजीवी कीट, *कोकोफेगस* स्पे. की सक्रियता के कारण शल्क कीटों की संख्या को बहुत निम्न स्तर (१.९ शल्क प्रति पत्ती) तक नियंत्रित कर देते हैं। *क्रिप्टोलीमस मोन्ट्रूजिएरी* के लारवों के लिए, एबेमेक्टिन १.९ ई सी (०.८ मि.ली./ लीटर), फिप्रोनिल ५ एस सी (९.५ मि.ली./लीटर), नोवेल्यूरॉन १० ई सी (०.७५ मि.ली./ लीटर) और ल्यूफेनुरॉन ई सी (०.८ मि.ली./लीटर) बहुत सुरक्षित पाया गया।

आम वृक्ष के फुदकों, *आसीन्डस हीरोज* के रेडयूविड परभक्षी कीट को अपना जीवन चक्र पूर्ण करने के लिए ५५ दिनों का समय लगा। (भारतीय बागवानी अनुसंधान संस्थान, बेंगलोर)

शीतोष्ण फल फसलें

जून महीने के दौरान पत्ती गिराने वाली बीटिल ब्राह्मीना कोरीएसी की ब्यूवेरिआ ब्रोन्गिनिआर्टि के द्वारा सात सप्ताहों में पहले, दूसरे और तीसरे निरूप के ग्रब्जों के लिए क्रमशः ८३.३, ७६.७ और ६६.७% घातकता देखी गई। (डॉ. यशवन्त सिंह परमार उद्यान और वानिकी विश्वविद्यालय, सोलन)

मार्च से सितम्बर महीनों के दौरान सेन जोस शल्क कीट, *डायास्पिडॉयटोस पर्निसिओसस* के परजीवीकरण प्रतिशतता का निरीक्षण किया गया, इस परीक्षण में आँकडे दर्शाते हैं कि समन्वित कीट प्रबंधन (मार्च महीने के दौरान १.५% विन्टर तेल (ए टी एस ओ) का छिडकाव और मई महीने के अंतिम दिनों से अगस्त तक *एनकार्सिआ पर्निकोसी* को १५ दिनों पर छोडना) वाले बगीचों में शल्क कीटों का अधिकतम (४.७ से २३.६%) परजीवीकरण पाया गया। जुलाई से सितम्बर महीनों के दौरान परजीवी कीटों को प्लावित रूप से छोडने पर परजीवितता के स्तर को बढावा मिलता है जो कि शल्क ग्रसन के साथ महत्वपूर्ण सकारात्मक सहसंबंध दर्शाता है। (शेरे-कश्मीर कृषि विज्ञान और प्रौद्योगिकी विश्वविद्यालय, श्रीनगर)

साब्जी फसलें

भिंडी के फल बेधक के प्रति *बी टी* की तीन मात्राओं (२.०, १.५ औप १.० कि.ग्रा./हेक्टेअर दर से) के चार छिड़कावों का मूल्यांकन किया गया। *बी टी* का २.० कि.ग्रा./हेक्टेअर दर से पहले छिडकाव के बाद कोंपल तथा फलों का कीट द्वारा ग्रसन कम पाया गया। भिंडी पर *बी टी* का २.० कि.ग्रा./हेक्टेअर की दर से प्रयोग *इरिआस* स्पे. के प्रबंधन के लिए प्रभावी पाया गया। (पंजाब कृषि विश्वविद्यालय, लुधियाना)

बैंगन के कोंपल और बेधकों के प्रति *बी टी* का २.० कि.ग्रा./हेक्टेअर दर से प्रयोग अत्यधिक प्रभावी पाया गया, परिणाम स्वरूप फलों की क्षति न्युनतम (केवल १३.६%) पाई गई और एक आर्थिक लागत-लाभ अनुपात के साथ पूरे परीक्षण अवधि के दौरान फलों की पैदावार भी अत्यधिक प्राप्त हुई। (केरल कृषि विश्वविद्यालय, त्रिसुर)

पाइएरिस ब्रेसिके की अपेक्षा *बी टी* के (१.० कि.ग्रा./हेक्टेअर) और ईकोनीम प्लस (०.२%) से फूलगोभी में पत्ती क्षति को कम करने के लिए प्रभावी पाया गया। (डॉ. यशवन्त सिंह परमार उद्यान और वानिकी विश्वविद्यालय, सोलन)

सूक्ष्म जीवों में से, ब्यू. *बेसिआना* के व्यवसायिक विभेद को १ X१०^{८} बीजाणु/ मि.ली. की दर से प्रयोग बहुत प्रभावी पाया गया, जिसके द्वारा *पाइएरिस ब्रेसिके* के लिए ७२.३% घातक साबित हुए। (शेरे-कश्मीर कृषि विज्ञान और प्रौद्योगिकी विश्वविद्यालय, श्रीनगर)

वर्टिसिलियम लेकेनाई का १X१०^{१३} कोनिडिआ / हे. की दर से प्रयोग करने पर गाँठ गोभी में माहूँ के प्रति ७५% तक घातक सिद्ध हुआ, इसके बाद ब्यू. *बेसिआना* की १X१०^{१३} कोनिडिआ / हे. की दर से प्रयोग बहुत प्रभावी पाया गया। (शेरे-कश्मीर कृषि विज्ञान और प्रौद्योगिकी विश्वविद्यालय, श्रीनगर)

खरपतवार

परीक्षण प्रक्षेत्र में *साइप्रस रोटून्डस* घास पर एक बेधक कीट अभिलेखित किया गया, जिसका ग्रसन घास पर कम ही पाया गया। (असम कृषि विश्वविद्यालय, जोरहट)

टर्फ घास की सफेद लट (व्हाईट ग्रब)

टर्फ घास की सफेद लट (व्हाईट ग्रब) के प्रति स्थानीय *मेटारहाईजियम एनाईसोप्लिए* का १X१०^{१२} बीजाणु / मि.ली. की दर से प्रयोग बहुत प्रभावी पाया गया। (शेरे-कश्मीर कृषि विज्ञान और प्रौद्योगिकी विश्वविद्यालय, श्रीनगर)

पोली हाऊस के हानिकारक कीट

पोली हाऊस में मिर्च के थ्रिप्सों के प्रति *वर्टिसिलियम लेकेनाई* का १X१०^{१०} कोनिडिआ / हे. की दर से प्रयोग करना प्रभावी पाया गया। (महात्मा फुले कृषि विद्यापीठ, राहुरी)

केरल में, जरबेरा के माहूँ के प्रति ब्यू. *बेसिआना*, *हि. थोम्पसोनाई* और वर्टिसेल (*वर्टिसिलियम लेकेनाई* का व्यवसायिक संयोजन) के तीन छिडकाव एक समान प्रभावी पाए गए। (केरल कृषि विश्वविद्यालय, त्रिसूर)

भण्डारण के हानिकारक कीट

भण्डारण में, चने के पीडक कीट, *केलोसोब्रुकस चाइनेन्सिस* की संख्या को कम करने के लिए *मेटारहाईजियम एनाईसोप्लिए* का प्रयोग बहुत प्रभावी पाया गया। (पंजाब कृषि विश्वविद्यालय, लुधियाना)

मेटारहाईजियम एनाईसोप्लिए के साथ पृथक बी बी -११ की तुलना में ब्यू. *बेसिआना* के पृथकों के प्रयोग द्वारा अत्यधिक घातकता देखी गई और उत्कृष्ट पाए गए। (जैविक नियंत्रण परियोजना निदेशालय, बेंगलोर)

3. EXECUTIVE SUMMARY

In order to develop biocontrol technologies for the eco-friendly management of key pests, diseases and weeds, an extensive programme covering both basic and applied research was under taken 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 the All-India Co-ordinated Research Project (AICRP) on biological control during 2005-06. Emerging problems like the sugarcane woolly aphid, eco-friendly management of sucking pests on *Bt* cotton, and integration of biological control in organic farming, were included in the programme. Most of the experiments assigned under the technical programme drawn for the year 2005-06 have been carried out successfully.

Basic research

Project Directorate of Biological Control, Bangalore

Biosystematics

The genera *Nedina* and *Neojauravia* were synonymised with *Protothea* and *Pharoscymnus*, respectively. *Neojauravia naeida* was synonymised with *Pharoscymnus flexibilis*. *Sticholotis quadrisignata rugicollis* was found to be a distinct species and a new senior synonym of *S. gomyi*.

Lophosia excisa (Cylindromyiini) from *Cyclopelta siccifolia* (Pentatomidae) and *Cylindromyia rufipes* (Cylindromyiini) from *Tolumnia* sp. (Pentatomidae) were recorded. Parasitism by *Carcelia illota* to an extent of 11% and *Goniophthalmus halli* to an extent of 2% was recorded on *Helicoverpa armigera* on pigeonpea and lablab. Parasitism by *Sturmiopsis inferens* to an extent of 5% was recorded on *Chilo partellus*.

Introduction of natural enemies

Renewed import permits for *Smicronyx lutulentus*, *Nephaspis bicolor*, *Ganaspidium nigrimanus* (=*utilis*), *Chrysocharis oscinidis*, *Delphastus pusillus*, *Telenomus triptus*, *T. laeviceps* and *T. ullyetti* were obtained from the Plant Protection Advisor to the Government of India.

Field releases of stem gall fly, *Cecidochares connexa* against *Chromolaena odorata* at the University of Agricultural Sciences, Bangalore, resulted in significant decrease in several plant growth parameters. The gallfly has spread to a distance of 25 m in the north and 50 m in south, east and west directions from the release spot in its first generation.

Parasitisation of the spiralling whitefly by *Encarsia guadeloupae* was the highest on *Michaelia* sp. (83.3%) during November 2005. The per cent parasitisation was above 80 in guava and *Cassia* sp. during November.

Interaction studies revealed that *Trichogrammatoidea bactrae* parasitised more number of eggs (51.5%) than *Trichogramma brassicae* (48.5%) when both were simultaneously exposed to *Corcyra* eggs.

Rearing and evaluation of natural enemies

When *Blaptostethus pallescens* nymphs were released on *Sitotroga cerealella* infested rice in the ratio of 1:5, the pest emergence was 11.1, 4.4 and 16.3% for 1, 2 and 3 releases, respectively, while the corresponding figures for *C. exiguus* releases were 2.2, 1.1 and 0%. The anthocorid predator, *Xylocoris flavipes*, was obtained from jowar storage bins.

Butter paper and wax paper as oviposition substrates for *Spodoptera exigua* resulted in 53.6 and 46.4%, egg laying, respectively. Per cent hatching was higher (67.8%) on the former.

In cage studies conducted to study the effect of kairomones on the performance of *Campoletis chlorideae*, treated batches (with larval wash of 9-day-old *Spodoptera litura* larva) gave higher parasitism (40.2%) compared to control (25.0%).

Parasitised egg cards of *Telenomus remus* of different ages (3-5, 6-8 and 8-10-day-old) were stored at 15±2°C (60±2% RH) for different durations. It was observed that 6-8-day-old eggs could be stored up to 10 days as 95.4% and 89.5% emergence was recorded after 5 and 10 days of storage, respectively.

Orius tantillus and *B. pallescens* preferred unparasitised eggs of *Corcyra cephalonica* and *H. armigera* in choice and no-choice tests in comparison to parasitised eggs.

Host-range tests for *Micromus igorotus*, indicated larval survival on 11 aphid species and non-survival on seven non-aphid hosts. *Micromus igorotus* laid the maximum number of eggs when reared on *Pseudoregma bambusicola* (799.9 eggs/female) while it was the least on *Ceratovacuna lanigera* (590.2 eggs/female). The sex ratio was always female-biased with 60% females and 40% males.

The egg, larval and pupal period of *Cryptolaemus montrouzieri* on *Sitotroga cerealella* ranged from 5.10-8.12, 15.7-24.12 and 7.59-10.2 days, respectively. Total average life cycle ranged from 37.8 to 39 days. Maximum average fecundity was obtained on maize (129.6 eggs/female), followed by paddy (119.9 egg/female). In an improved version of the adult oviposition cage, 78.1% eggs could be collected on substrates and the cage could be used for four days. A new moth collection device was fabricated with the advantages of non-disruption of the rearing regime, direct moth collection in oviposition cage and less adult handling.

Sugarcane woolly aphid predator, *Dipha aphidivora* completed its life cycle on the two-tailed mealybug, *Ferrisia virgata*.

Lower leaves of the sugarcane plant were found to harbour more number of woolly aphids than the top. As the plant grew older, the aphids began colonizing the upper leaves. The proportion of soldiers in *C. lanigera* (10-12%) colonies was found to be lower than that in *P. bambusicola* (22-24%) colonies. A non-significant positive correlation existed between the colony size, colony density and natural enemy population.

Use of insect viruses

Several adjuvants were evaluated individually against second instar larvae of *H.armigera* for their efficacy along with *Ha*NPV exposed to an irradiation of 500 W/m^2 for a period of 90 minutes using sun test machine (which simulates the natural sun light). Four adjuvants (viz. soybean flour (10%), Tinopal (0.2%), molasses (5%), CSKE (10%)) along with virus resulted in more than 85% larval mortality, while boric acid (1%) and turmeric (2%) recorded a larval mortality of 82.3% and 74.4%, respectively.

In the case of *Spodoptera litura*, Tinopal (0.1%) gave maximum larval mortality of 81.81% as compared with 39.2% larval mortality of irradiated *Sl*NPV without any adjuvant. The combination of *Sl*NPV + CSKE (62.5%) +corn oil 1.5% + crude sugar 25% + Tween (0.04%) was the most effective in increasing the mortality due to *Sl*NPV (95.2%).

Entomofungal pathogens

Addition of 0.2% colloidal chitin to the production medium or 2% pure chitin to the talc formulation or combination of these treatments extended the shelf-life of *Beauveria bassiana* to 8 months at room temperature (17-32°C), while addition of these to the production medium of *Metarhizium anisopliae* extended the shelf-life to 8 months at room temperature.

In the case of *Nomurea rileyi*, addition of 0.2% colloidal chitin to the production medium or addition 2% pure chitin to the talc formulation reduced the colony-forming units (CFU) of *N. rileyi* (29.5×10^8/g, 24.7 $\times 10^8$/g, respectively) compared to the CFU in the talc formulation prepared from unamended medium (37.8×10^8/g).

Isolation and characterization of indigenous *Bacillus thuringiensis* strains

Twenty-seven native *Bt* isolates were isolated and crystal presence was seen in 15 of them. Twenty-one forest soil samples were collected from Chhattisgarh and seven *Bt* isolates were purified on *Bt*-specific media. The LC_{50} values were calculated for four of the *Bt* isolates against *Plutella xylostella* and compared with the standard HD-1 strain. The highest toxicity was observed with the isolate *Bt*4 (log 5.83 spores/ml) and the lowest with *Bt*8 (log 7.97 spores/ml).

Isolation of endophytic bacteria

Endophytic bacteria were isolated from healthy chickpea plants for the first time and were identified as *Bacillus megaterium* (MTCC6533), *Bacillus* sp. (MTCC6535), *Bacillus circulans* (UAS6534), *Erwinia herbicola* (UAS6720) and *Enterobacter agglomerans* (MTCC6536). Two rhizospheric isolates from healthy tomato plants showed antagonism against *Fusarium oxysporum* f.sp. *lycopersici*. The isolates were purified and identified as *Pseudomonas aeruginosa* (MTCC7512) and *Cryptococcus albidus* (MTCC7436).

Plants treated with *B. megaterium* in the greenhouse showed highest vigour index of 4116.67. Seed bacterization with endophytic bacteria resulted in peak phenol content at 4 days and was highest with *B. megaterium* (505µg/g) compared to control (290µg/g).

Pathogens for the biological suppression of phytophagous mites

In studies on the viability of *Hirsutella thompsonii* and *H. thompsonii* var. *synnematosa* pellets in sterile water under non-refrigerated (room) and refrigerated conditions, the pellets from the fridge survived up to 13 months of storage with growth rates of 0.89 mm and 0.96 mm/day for *H. thompsonii* and *H. thompsonii* var. *synnematosa*, respectively.

Six isolates of *H. thompsonii* var. *synnematosa* [MF(Ag)27 to 32] were multiplied on 10 different agar media. The radial growth and synnemata production of *H. thompsonii* var. *synnematosa* were found to be the best on oat-meal agar (OMA). The maximum growth of 64.33 mm with a growth rate of 1.95 mm/day was observed in MF(Ag)32.

The effect of different surfactants on the biomass characteristics of *H. thompsonii*.indicated that Tween 80 was the best based on number of CFUs, pellet number, wet and dry weights, but not the pellet size. The numbers of CFU obtained with Tween 80 was 2.4 times more than that produced in control (unamended).

A new liquid medium based on tomato was developed to replace the commonly used potato dextrose broth (PDB) for the mass production of *H. thompsonii*.

Folic acid at a concentration of 200 µg/ recorded the maximum number of CFU of *H. thompsonii*, a 2.9-fold increase followed by 100 µg/l concentration which showed 2.6-fold increase over control. Biotin was able to increase conidial production (7.5 µg/l).

The exudate from sporulating culture of *H. thompsonii* had an ovicidal effect and reduced hatching (64.6%) of the eggs of *Tetranychus urticae*. The exudate also showed toxicity to nymphs of *T. urticae*. An adult female feeding on exudate-treated leaf could lay only 30.7 eggs compared to 51 eggs laid by the mite feeding on untreated leaf over a period of 7 days.

When the effect of *H. thompsonii* in combination with carboxy methyl cellulose (CMC) and gum acacia was assessed on okra, CMC recorded higher mite mortality of 93.5 and 95.3% after the 1st and 2nd sprays, respectively.

Fungal antagonists

Trichoderma viride

Among the *Trichoderma viride* isolates (27 isolates) screened against *Sclerotium rolfsii* and *Fusarium ciceri*, Tv2, Tv12, Tv21, Tv23,Tv25, Tv34 and Tv35 were found to be better against *S. rolfsii*. Against *F. ciceri*, Tv4 and Tv12 were found to be superior based on dual plate studies. On colloidal chitin and *S. rolfsii* cell wall-amended media, the growth of isolates Tv4, Tv8, Tv10 was faster on solid medium and on liquid medium, growth of Tv32, Tv35, Tv36 and Tv29 was high. Exochitinase activity was high in the isolates Tv3, Tv8, Tv10, Tv23, Tv25, Tv28, Tv30 and Tv32 while endochitinase activity was high in the isolates Tv3, Tv16, Tv22.

Addition of colloidal chitin at 0.1 and 0.2 per cent helped in maintaining the high CFU in the formulations of *T. viride*. Addition of colloidal chitin extended the shelf-life by 2-3 months.

Addition of glycerol at 3 and 6% increased the CFU count in the formulations for up to 8 months. In *T. viride* also, addition of glycerol helped in retaining high CFU for up to 7-8 months when added at 3-6% concentration in production media.

For up to six months of shelf-life, formulations from the biomass subjected to heat shock had high CFU compared to control.

Trichoderma virens

Six isolates of *T. virens* were found to be effective against *S. rolfsii.* The exochitinase activity was high in liquid cultures of *T. virens* (TVS4, TVS-ITCC, TVS-CPCRI and TCS12) grown on colloidal chitin.

Trichoderma harzianum

Twenty-eight isolates of *T. harzianum* were tested for their antagonistic potential against *Phytophthora parasitica* var. *nicotianae* in dual culture. The percentage reduction in *P. parasitica* var. *nicotianae* was very high in isolate Th-9, followed by the isolates Th-5, Th-GTH7, Th-1, Th-2, Th-3, Th-8, Th-7, Th-21, Th-ITCC, Th-12 and Th-CPCRI.

Addition of chitin to the formulation of *T. harzianum* resulted in higher CFU in the formulation for up to 6 months while in the control the CFU went down below the recommended level of 2 x 10^6 after 4 months.

Entomopathogenic nematodes

Higher yields of *Steinernema carpocapsae* were obtained on Wouts medium supplemented with casein peptone (62 - 89 lakhs per 4 g of the medium). *S. abbasi* and *S. carpocapsae* caused mortality of *H. armigera* larvae at 12 h, at 50 and 125 IJs/larva respectively. *Heterorhabditis indica* and *H. bacteriophora* caused mortality at 24h. *S. abbasi* was found effective against *H. armigera* with least LD_{50} followed by *S. carpocapsae, H. indica* and *H. bacteriophora.* Nematodes survived well in glycerine and castor oil for up to 45 days under storage in lab and pathogenicity was not adversely affected. Sodium sulphate (0.25-1%) as UV protectant protected *S. carpocapsae* and *H. bacteriophora.* Gum-based gel formulation was suitable for storage and transport of *S. carpocapsae* IJs @ 40x10^5 /100ml with viability for 30 days at 30°C. *H. indica* in talc @5 b /ha controlled *Holotrichia* in tobacco fields in Shimoga increasing establishment of transplants and the cured leaf yields.

Biological suppression of plant parasitic nematodes

β-tubulin gene (270 bp) of native isolate of *Pochonia chlamydosporia* (PDBC PC56) was sequenced and deposited with NCBI GenBank, Maryland, USA (Accession no. DQ417603).

Sheep droppings and vermicompost enhanced the bioefficacy of *Arthrobotrys oligospora* against root-knot and reniform nematodes in eggplant and cotton under pot conditions.

Solid, liquid and di-phasic media from natural sources were identified and protocols for enhancing the production cycles and yield of *A. oligospora* in a given set of conditions standardized.

Studies on induced systemic resistance by *Pseudomonas fluorescens* formulations for the control of root-knot nematode in tomato indicated that the plant growth was better (in terms of plant height, fresh weight and dry weight) in treated plants than in untreated.

Soil solarization using plastic mulches for 21 days during May-June followed by the incorporation of *P. chlamydosporia* (2x10^{10} spores/m^2) and neem cake (1kg/m^2) before sowing of tomato seeds in the nursery recorded higher fungal CFUs/g in the soil after two months and better root colonization compared to the incorporation of the fungus and neem cake without mulching.

Incorporation of *Paecilomyces lilacinus* or *P. chlamydosporia* talc formulations at 30 kg/ha along with 200kg/ha of vermicompost in furrows before sowing gherkin seeds recorded 54-72% infection of egg masses of root-knot nematode, reduction in the nematode populations by 22-38% in soil and 38-66% reduction in root infection in 75 days of crop growth.

Behavioural studies on natural enemies

Volatile organic compounds were trapped, isolated and identified from a fern, *Chenopodium* sp. and basil leaves (*Ocimum sanctum*). Twenty-eight compounds were identified from fern leaves.

Mixture of four plant volatiles, i.e. pentacosane+tricosane+heptacosane+octocosane in the ratio of 1:3:1:1 at 50% concentration was quite attractive to 4-day-old *Chrysoperla carnea* adults as indicated by mean Excess Proportion Index.

Methyl salicylate was recorded as an attractant to several species of predators. Plants exposed to methyl salicylate for 24 and 48 hours recorded higher oviposition by *C. carnea* in cotton.

Development and evaluation of improved strains

A *Chrysoperla carnea* strain was developed for tolerance to variable low temperature (18°-24°C).

A low temperature-adapted strain of *T. chilonis* (18-24°C) was developed after rearing for 30 generations under laboratory conditions. The development, searching ability and biological parameters of low temperature-adapted strain of *T. chilonis* was studied in comparison with the strain reared in the laboratory at ambient temperature in cage studies. Fifty-eight per cent eggs were parasitised by the low temperature-adapted strain as compared to 17.2% by the non-adapted strain.

A technique was standardized to isolate DNA from *Trichogramma* spp.for PCR and RAPD-PCR. An amplification of 600bp and 550bp was observed using ITS-1and ITS-2 primers, respectively. The ITS2 region of seven species/strains of trichogrammatids were sequenced and the sequences were deposited with GenBank (accession nos. DQ220703 (*Trichogramma chilonis*), DQ314611 (*T. brassicae*), DQ381281 (*T. brasiliense*), DQ381280 (*T. evanescens*), DQ381279 (*T. mawanzai*), DQ344045 (*T. dendrolimi*), DQ344044 (*T. embryophagum*)).

Releases of multi-insecticide tolerant strain (MITS) of *T. chilonis* gave 34.1% egg parasitisation of *H. armigera* in tomato and it was significantly higher compared to that recorded in laboratory strain released plots or natural parasitism in farmer's practice plots.

Artificial diets for predators

Females of *Orius tantillus* were found to lay eggs (11 eggs/female) and survived for 10 days on the refined artificial diet based on soybean hydrolysate and yeast extract.

Populations of *C. montrouzieri* collected from Pune were reared on beef liver based artificial diet and compared with population of PDBC. There was no significant difference in larval and pupal periods, pupation (%) and adult emergence (%) between these two populations when reared on artificial diet.

Beef liver-based artificial diet was better than pig liver-based artificial diet for the rearing of *C. carnea*.

DNA extraction procedure was standardized for chrysopid and coccinellid predators. PCR amplification of ITS-2 regions of artificial diet and natural diet reared *C. carnea* (600 bp) and *C. montrouzieri* (600 bp) revealed no difference.

Artificial diets for host insects

A semi-synthetic diet consisting of toddy palm leaf powder and defatted soy has been developed for rearing *Opisina arenosella*. The late larval parasitoid, *Goniozus nephantidis* and pupal parasitoids, *Brachymeria nosatoi* and *B. nephantidis,* were successfully multiplied on the artificial diet-reared host. A semi-synthetic diet was developed for *Spodoptera exigua*. *Zygogramma bicolorata* could be reared on a semi-synthetic diet comprising parthenium leaf extract.

Software development

Information on four vegetables – beans, brinjal, potato and tomato-and their insect pests was incorporated in the software. A database on microbial bioagents is under development. The software Map info Professional (Version 7.5) has been procured and installed in ARIS Cell.

Biological Suppression of Crop Pests

Sugarcane

Borers

Release of the high temperature-tolerant strain of *Trichogramma chilonis* developed by PDBC @ 50,000/ha was on par with chemical control for the control of early shoot borer and reduced the incidence by 50-53%. The cost:benefit ratio was 1:7.4 as compared with 1:3.8 in chemical control. Large-scale demonstration of the effectiveness of *T. chilonis* was carried out over an area of 1440 ha in farmers' fields in collaboration with two sugar mills in Punjab. Release of *T. chilonis* @ 50,000/ha at 7-10 days interval during July-October resulted in reduction of stalk borer incidence by 66.7% (PAU).

Field evaluation of *T. chilonis* against *Chilo tumidicostalis* revealed that the mean per cent incidence in released plot was 20% against 45% in the unreleased plot and post release egg parasitism was 34% against 12% in the farmers' practice. The biocontrol plot registered higher yield (78 t/ha) than control plot (54 t/ha) (AAU(J)).

Woolly aphid

Sugarcane woolly aphid (SWA) infestation was low (9.14%) in nine agro-climatic zones of Maharashtra covering 64,906 ha cropped area under infestation. The population of predators was low (*Dipha aphidivora* and syrphids) to moderate (*Micromus igorotus*). Release of *D. aphidivora* @ 1,000 larvae/ha significantly reduced the SWA population within 45 days as compared to farmers' practice. Total life cycle of *D. aphidivora* was completed in 54.3 days. The mass production of *D. aphidivora* on SWA was carried out on SWA population raised on sugarcane (7 month-old) inside shade nets (50 gauge mesh) with bamboo structures (5x4x4 m), which yielded 1230 larvae/pupae of the predator/shade net within two months (MPKV).

In Tamil Nadu, the incidence of woolly aphid was maximum during July and the infestation declined from July to January. Increase in the intensity of aphid was noticed during March 2006. Maximum temperature and relative humidity showed negative correlation with the SWA population, while minimum temperature and relative humidity showed positive correlation. Rainfall and wind speed showed significant negative correlation with the SWA population. Weather parameters had no significant effect on *D. aphidivora* and *M. igorotus* populations (TNAU).

Dipha aphidivora and *M. igorotus* colonization in shade net was dependent on the intensity of infestation of *C. lanigera* in the net house. A mean of 4.2 *Dipha* cocoons / leaf and 0.07 *Micromus* grubs per leaf could be harvested. Release of *Dipha* resulted in 93.6 - 97.2 per cent control after four months. There was no competitive elimination of either predator at different densities and both were able to survive in the same niche without exerting negative effect on the other (TNAU).

At Coimbatore, the activity of SWA and *Dipha* was generally higher during October - January. A simple laboratory mass culture technique was attempted for rearing *D. aphidivora* on aphid colonized leaf bits. *D. aphidivora* releases significantly enhanced its numbers and reduced aphid intensity (SBI).

No woolly aphid incidence was recorded during surveys in zones of various sugar mills of Haryana conducted in monsoon and post-monsoon periods (CCSHAU).

Encarsia flavoscutellum brought from Jorhat failed to establish in Medak and Sangareddy districts in Andhra Pradesh (ANGRAU).

At Buralikson, Golaghat, Assam, the population build up of SWA had a significant positive correlation with maximum (r=0.062) and minimum (r=0.734) temperature. Similarly, *Micromus* and syrphids also had significantly positive correlation with maximum and minimum temperature, whereas *D. aphidivora* showed a positive correlation (r=0.709) with maximum temperature (AAU(J)).

There was significant positive correlation (r=0.0905) between maximum temperature and SWA population. *D. aphidivora* population showed significant negative correlation (r = -0.802) with the aphid population. Per cent loss in sugar recovery and weight due to SWA ranged from 9.95 (CoS 8436) to 19.80 (CoS 767) and 10.56 (CoS 8436) to 20.45 (CoS 767), respectively (IISR).

Cotton

In BIPM trials on *Bt* cotton at two locations in Punjab, there was no significant difference among the *Bt* and non-*Bt* hybrids as the pest population was low. Natural enemy population was higher (0.82) in habitat management plot followed by BIPM (0.68) and very low in insecticidal control (0.06). The population of sucking pests and bollworms was low in all the treatments (PAU).

The sucking pest complex was comparatively lower on *Bt* cotton+BIPM than in farmers' practice mainly due to the activity of natural enemies. As regards *Helicoverpa armigera*, *Bt* cotton fared better both in BIPM and farmers' practice (FP) than non-*Bt* cotton (ANGRAU).

Under BIPM, *Bt* cotton recorded less *H. armigera* and *Earias vitella* populations, less bollworm damage and higher yield. The incidence of sucking pests was low in *Bt* FP module. The BIPM modules recorded significantly higher number of natural enemies than the FP modules (TNAU).

Bt cotton with existing package of practices was effective in suppressing the population of aphids, jassids, thrips and whiteflies and recorded maximum yield. The population of predators was however, maximum in *Bt* cotton plots with BIPM package (MPKV).

Bt cotton+BIPM package recorded significantly low bud and boll damage, locule damage due to *E. vittella* and *Pectinophora gossypiella* and population of sucking pests as compared to all the other treatments giving highest seed cotton yield. Population of various natural enemies was also higher in *Bt* cotton + BIPM and non-*Bt* cotton + BIPM package compared to other two treatments indicating adverse effect of insecticides used in the package (AAU(A)).

Tobacco

Parasitisation of *H. armigera* and *S. litura* in tobacco with trap crops was 1.13 and 1.30 times higher, respectively, than that in tobacco as sole crop. Significantly higher reduction in damage by the pests was also observed if tobacco was grown with trap crops. *N. rileyi*, *B. bassiana* and *B.t. kurstaki* were equally effective in containing leaf damage caused by *S. exigua*. The trap crops *Tagetes* and castor effectively suppressed *H. armigera* and *S. litura*, respectively (CTRI).

Pulses

Under controlled conditions in laboratory bioassays, *Bt* caused 53.2% mortality in the treated larvae of *H. armigera*. Under field conditions, 2 kg/ha dose of the formulation fared comparatively better in terms of larval population and extent of infestation (ANGRAU).

Against pod borers of pigeonpea in the laboratory, *Bt* caused high mortality of *H. armigera* while slightly lower mortality was observed in *Maruca testulalis*. In field studies, it was evident that *Bt* @ 2 and 1 kg/ha were significantly superior to NSKE treatment and were on par with each other in reducing *H. armigera* and *M. testulalis* population after five and seven days of sprays, respectively, when pod yield was recorded (AAU(A)).

Rice

Rice cultivation with organic inputs was compared with chemical control. In the case of stem borer, a significantly high dead heart symptom was recorded in conventional farming. Grain yield was on par in conventional and organic farming. Significantly higher population of natural enemies such as spiders and coccinellids was found in organic farming than in conventional farming during kharif and rabi seasons (KAU).

The infestation of rice stem borer (4.3%) and white ear head (5.3%) were lower in the organic package plot against 10.8% and 11.0% in the farmers' practice plot. The leaf folder population was also lower (3.0%) than that in the farmers' practice (7.4%) plot. The organic plot registered higher yield (3602 kg/ha) against farmers' practice (2706 kg/ha). In cost:benefit analysis, the organic package plot gave the highest net profit (AAU(J)).

Two sprays of *Bt* formulation at three doses tried (2,1.5 and 1 kg/ha) were equally effective in reducing the population of rice leaf folder, case worm, skipper, hairy caterpillar, etc. throughout the period of observation. Similar results were recorded both in kharif and rabi seasons (KAU).

Bt irrespective of the dose was effective in reducing the population of stem borer and leaf folder (AAU(J).

Sprays of *Bt* @ 2.0kg/ha was effective for the management of leaf folder and stem borer on both coarse and basmati rice. Seven 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 (PAU).

Oilseeds

In laboratory screening, mustard sawfly was susceptible to all the entomopathogens to varying degrees with lowest LC_{50} values for *Bt* (DOR strain) (0.948 g/l), followed by Biolep (commercial *Bt* formulation) and highest for *M. anisopliae* (AAU(A)). In the field, *Bt* @ 2.0 kg/ha was the best treatment in controlling mustard sawfly after 10 days of application (AAU(A)).

Coconut

Releases of *Trichogramma embryophagum*, *Goniozus nephantidis* and *Cardiastethus exiguus* against *Opisina arenosella* for the last two years at Vatanapilly beach area in Kerala proved to be effective (KAU). *Oryctes* baculovirus-treated adults were released in one ha area and the manure pits were treated with *M. anisopliae*. After one month, fresh incidence was reduced in the observation palms. In manure pits *Metarhizium* infection was 100% on grubs (KAU).

Tropical fruit crops

On guava, *Encarsia guadeloupae* effectively parasitised spiralling whitefly from June (56.2%) to August (96.3%) and kept the whitefly population under minimum level.

Effectiveness of *Cryptolaemus montrouzieri* against mealybugs on grape vine and *Encarsia guadeloupae* against spiraling whitefly on guava was well demonstrated in farmers' fields in Karnataka. Releases of *C. montrouzieri* were found to be effective in clearing the mealybugs on pomello. A mean of 36.8 reduction in plant infestation and 18.9% reduction in fruit infestation was observed with the release of *C. montrouzieri* on custard apple.

The population of green scale, *Coccus viridis*, on sapota was highest on July (11.8/leaf) and due to the activity of key parasitoid, *Coccophagus* spp. the scale insects were brought to a very low level (1.1/leaf). Abamectin 1.9EC (0.5ml/l), fipronil 5 SC (1.5ml/l), novaluron 10 EC (0.75ml/l) and lufenuron 5EC (0.8ml/l) were found to be very safe to the larvae of *C. montrouzieri*.

The reduviid predator of mango hoppers, *Isyndus heros* took 55 days to complete the life cycle (IIHR).

Temperate fruit crops

Natural mortality of defoliating beetles of *Brahmina coriacea* by local strain of *Beauveria brongniartii* was observed in June. With *B. brongniartii*, the maximum kill of the first, second and third instar grubs was 83.3, 76.7 and 66.7% in 7-weeks, observation (Dr. YSPUH&F).

Observations were made on the per cent parasitisation of San Jose scale, *Diaspidiotus perniciosus*, during March-September and the data revealed maximum scale parasitisation (4.7-23.6%) in IPM managed orchard (spray of 1.5% winter oil (ATSO) during March and fortnight releases of *Encarsia perniciosi* from late May to August). Increase in level of parasitism was found directly related to augmentative releases of parasitoids indicating significant negative correlation with scale infestation from July-September (SKUAS&T).

Vegetable crops

Four sprays of *Bt* at three doses (2.0, 1.5 and 1.0 kg/ha) were evaluated against the fruit borer of okra. The shoot and fruit infestation recorded after first spray was lowest in *Bt* @ 2.0 kg/ka (KAU). *Bt* @ 2 kg/ha proved to be effective for management of *Earias* spp. on okra (PAU)

Bt @ 2.0 kg/ha was found to be the most effective against brinjal shoot and fruit borer with lowest fruit damage (13.6%) and the fruit yield was significantly high throughout the period of observation with an attractive cost-benefit ratio (KAU).

Btk (1.0 kg/ha) and Econeem Plus (0.2%) proved effective in reducing the leaf to just half as compared with the control by *Pieris brassicae* on cauliflower. (Dr.YSPUH & F). Among the microbials, commercial strain of *B. bassiana* @ $1x10^8$ spores/ml proved most effective, causing 72.3% mortality of *Pieris brasicae* (SKUAS&T).

Verticillium lecanii @ 10^{13} conidia/ha was most promising, causing 75% mortality of aphids on knol-khol followed by *B. bassiana* @ $1x10^{13}$ conidia/ ha (SKUAS&T).

Weeds

A borer was recorded on *Cyperus rotundus* in the experimental farm with low incidence (AAU(J)).

White grubs on turf grass

A local isolate of *Metarhizium anisopliae* @ $1x10^{12}$ spores/ml proved most promising against white grubs on turf grass (SKUAS&T).

Polyhouse crop pests

Spraying of *V. lecanii* @ 10^{10} conidia/l was found effective against thrips on chilli in polyhouses (MPKV). Three sprays of *B. bassiana*, *V. lecanii*, *H. thompsonii* and Verticel (a commercial formulation of *V. lecanii*) were found to be equally effective against aphids on gerbera in Kerala (KAU).

Storage pests

Metarhizium anisopliae significantly decreased the population of *Callosobruchus chinensis* on chickpea in storage (PAU). *Beauveria bassiana* isolates caused higher mortality and mycosis compared to *M. anisopliae*, with Bb-11 isolate proving to be the best (PDBC).

Transfer of technology

The technology on the control of spiralling whitefly with use of parasitoid *Encarsia guadeloupae* on guava, control of grape mealybug with use of predator *Cryptolaemus montrouzieri*, control of sugarcane woolly aphid with predators and biological control in *Bt* cotton and organic rice were demonstrated in farmer's fields.

Human resource development

Twelve scientists of the PDBC were trained in different institutes with in India on various aspects of biological control and three scientists participated in different symposia held overseas. The Project Directorate of Biological Control organized 21 training programmes on different aspects on biological control during the year 2005-06 in which 99 scientists representing ICAR Institutes, SAUs, State Departments of Agriculture and Horticulture and commercial production units participated.

Revenue generation

A total of Rs.13.35 lakhs revenue was generated by the Project Directorate which include cosultancy, sale of technical bulletins and natural enemies.

Publications

During the period 67 research papers were published in scientific journals, 72 research papers were presented during symposia/conferences and 37 papers/reviews were contributed as book chapters, technical bulletins and popular articles.

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), ICAR included the project under its research activities with full financial support. Recognition of the importance of biological control came during the VIII plan with the upgradation of the centre to Project Directorate of Biological Control with headquarters at Bangalore. The Project Directorate started functioning on 19 October 1993. The AICRP started with 13 centres initially and has now increased to 16 centres, all functioning under the Project Directorate.

Past achievements

Basic research

- Eighty-seven exotic natural enemies (NEs) 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 mwanzai*, an egg parasitoid, introduced from Kenya for biological control of *Helicoverpa armigera* and other lepidopteran tissue borers was successfully quarantined.
- *Curinus coeruleus* (origin: South America), the coccinellid predator introduced from Thailand in 1988, colonized successfully on subabul psyllid.
- *Cyrtobagous salviniae* (Origin: Argentina) was introduced in 1982 and colonized on water fern, *Salvinia molesta*, in 1983. Weevil releases have resulted in savings of Rs.68 lakhs / annum on labour alone in Kuttanad district, Kerala.
- The weevils, *Neochetina bruchi* and *N. eichhorniae*, and the hydrophilic mite, *Orthogalumma terebrantis* (Origin: Argentina), introduced in 1982 and colonized in 1983 on stands of water hyacinth, have established in 15 states. Savings on labour alone is Rs. 1120 per ha of weed mat.
- The chrysomelid beetle, *Zygogramma bicolorata* (Origin: Mexico), introduced and colonized in 1983 on stands of parthenium, has established in all the states and Union Territories.
- The stem gallfly, *Cecidochares connexa*, introduced from Indonesia for the biological control of *Chromolaena odorata* in 2003 and was successfully quarantined and limited field releases were made.
- *Puccinia spegazzinii*, the rust fungus specific to *Mikania micrantha* imported through CABI, UK in 2003 was successfully quarantined in NBPGR, New Delhi and limited field releases were made.

- Biosystematic studies were carried out on 250 predatory coccinellids. A website on Indian Coccinellidae featuring image galleries of common species and their natural enemies has been constructed and hosted.

- A computer-aided dichotomous key to 10 common Indian species of *Chilocorus* is hosted on the internet.

- Biological control of sugarcane pyrilla has been achieved within the country by the redistribution of *Epiricania melanoleuca*, a parasite of *Pyrilla perpusilla*.

- Breeding techniques for 46 host insects standardized including rearing on semi-synthetic diet and cost of production has been worked out.

- Improved laboratory techniques developed for the multiplication of 26 egg parasitoids, seven egg-larval parasitoids, 39 larval/nymphal parasitoids, 25 predators and seven species of weed insects.

- A technique for shipping *Telenomus* cards in ventilated plastic boxes fixed with polystyrene strips (with slits) has been standardized.

- A beef liver-based semi-synthetic diet has been evolved for *Chrysoperla carnea* to facilitate its large-scale production and use.

- Toddy palm leaf powder-based artificial diet was developed for rearing *Opisina arenosella*

- Coccinellid predators, *Cryptolaemus montrouzieri*, *Cheilomenes sexmaculata* and *Chilocorus nigrita* successfully mass-produced on semi-synthetic diet.

- A new multi-cellular acrylic larval rearing unit devised for efficient and economic mass production of *Helicoverpa armigera* and *Spodoptera litura* for commercial production of host-specific parasitoids and NPV.

- The predators, *Micromus igorotus* and *Dipha aphidivora*, were identified for the management of sugarcane woolly aphid.

- A novel technique of modified atmosphere packing of *Corcyra cephalonica* eggs followed by low temperature storage at 8±1°C has been developed.

- Tritrophic relationships between natural enemies, their hosts and host plants have been determined.

- Tritrophic interaction studies between the egg parasitoid, *Trichogramma chilonis*, bollworm *H. armigera* and cotton, chickpea, pigeonpea, sunflower and tomato genotypes have helped in identifying biocontrol-friendly genotypes.

- Suitable low temperatures for short-term storage of trichogrammatids, *Eucelatoria bryani*, *Carcelia illota*, *Allorhogas pyralophagus*, *Copidosoma koehleri*, *Hyposoter didymator*, *Cotesia marginiventris*, *L. dactylopii*, *Sturmiopsis inferens*, and *Pareuchaetes pseudoinsulata* have been determined.

- An endosulfan-tolerant strain of *Trichogramma chilonis* (Endogram) developed for the first time in the world. Technology transferred to private sector for large-scale production.

- Strains of *Trichogramma chilonis* tolerant to multiple-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* (strain N24), 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 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.

- An easy and rapid technique to screen antagonistic fungi against plant parasitic nematodes has been devised to identify efficient strains. The antagonistic fungus, *Paecilomyces lilacinus* was found effective against *Meloidogyne incognita* and *Rotylenchulus reniformis* in red laterite soils and *Pochonia chlamydospora* was effective in sandy loam soil.

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

- 'PDBC-INFOBASE' giving information about bioagents, their use and availability in public and private sector in the country; and 'BIOCOT", giving information about biocontrol measures for cotton pests and a CD version of the software "Helico-info" were developed.

Applied research

- Eight releases of *T. chilonis* (@ 50,000/ha at 10 days interval) during April-June and six releases of *T. japonicum* (@ 50,000/ha at 10 days interval) during May-June have proved effective in suppressing sugarcane tissue borers.

- *Beauveria bassiana, B. brongniarti* and *Metarhizium anisopliae* were mass cultured and utilized effectively against sugarcane white grubs.

- *Encarsia flavoscutellum, Micromus igorotus* and *Dipha aphidivora* were promising against the sugarcane woolly aphid.

- Application of *Heterorhabditis indica* @ 2.0 billion IJs/ha resulted in minimum population of white grubs in sugarcane.

- *Trichogramma chilonis* has proved effective against maize stem borer, *Chilo partellus*.

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

- *Trichogramma japonicum* (1 lakh/ha) was as effective as *T. chilonis* in controlling the rice leaf folder.

- IPM modules for cotton crop have been formulated, comprising the use of oxydemeton methyl (0.03%), releases of *C. carnea, T. chilonis* and spray of *Ha*NPV. The module gave higher yields of seed cotton and conserved natural enemies better than insecticidal sprays alone.

- BIPM package recorded significantly lower bud and boll damage, lower population of sucking pests and higher seed yield than the package with chemical agents in *Bt* cotton.

- *Bt* and *Ha*NPV were important components of BIPM of pod borers in pigeonpea and chickpea resulting in increased grain yield.
- Release of *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 Biosystematics, Introduction and Quarantine Laboratory, Mass Production Laboratory, Pathology Laboratory, Entomophagous Insect Behaviour Laboratory, Biotechnology Laboratory and a Co ordination, Documentation and Training Cell (Fig. 1).

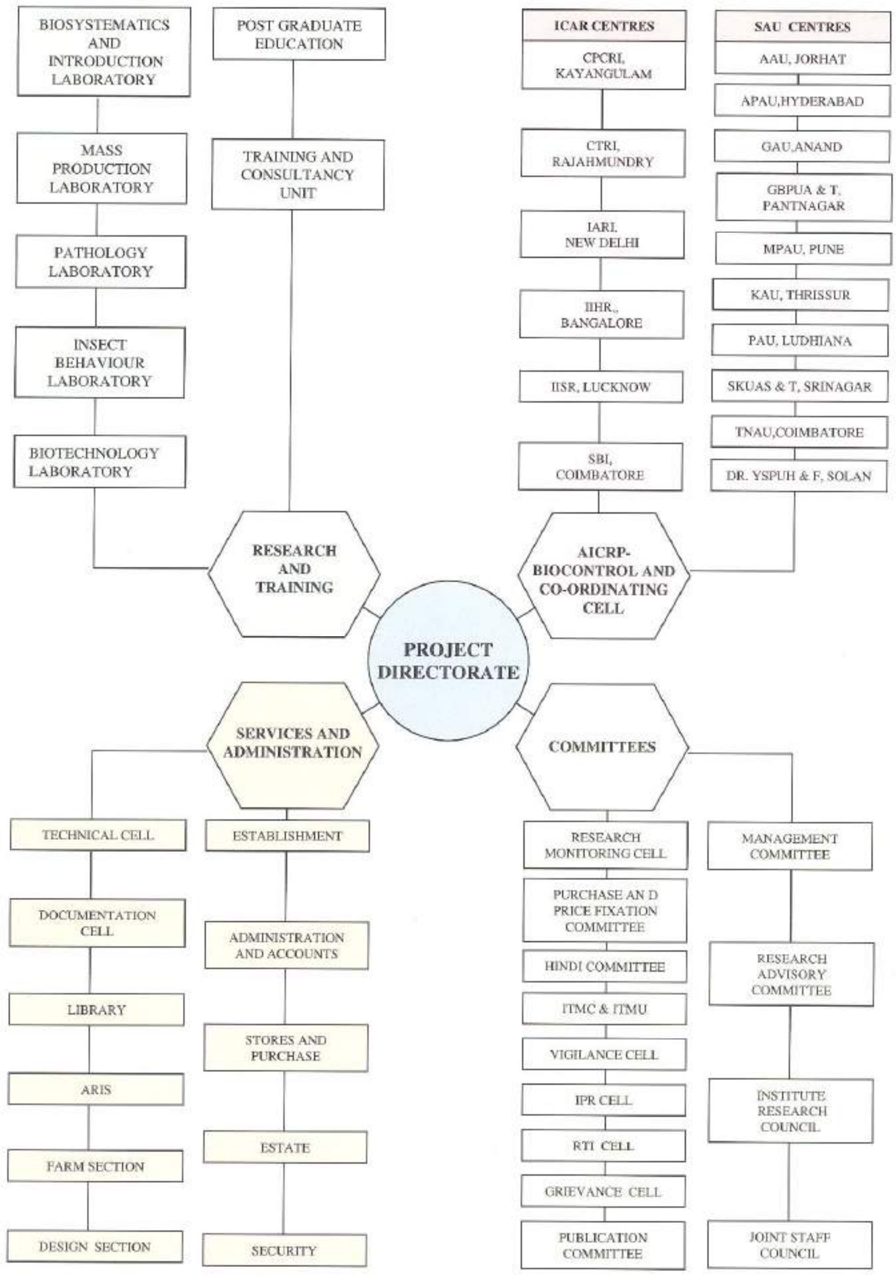

Fig. 1. The organizational chart

Financial statement (2005-06) (Rs.in lakhs)

Project Directorate of Biological Control, Bangalore

Head	Plan	Non-plan	Total
Pay & allowances	0.00	150.00	150.00
TA	3.00	3.00	6.00
Other charges including equipment	104.00	24.00	127.00
Information technology	1.00	-	1.00
Farm development	2.37	-	-
Works/petty works	19.63	40.00	63.00
Total	**130.00**	**217.00**	**347.00**

AICRP Centres (ICAR share only) expenditure (2005-06)

Name of the centre	Expenditure (Rs. in lakhs)
AAU, Anand	25.54
AAU, Jorhat	16.83
ANGRAU, Hyderabad	7.34
Dr.YSPUH&F, Solan	15.14
GBPUA&T, Pantnagar	2.18
KAU, Thrissur	18.63
MPKV, Pune	14.44
PAU, Ludhiana	15.01
SKUAS&T, Srinagar	5.13
TNAU, Coimbatore	10.78
Total	**131.02**

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

BASIC RESEARCH

Project Directorate of Biological Control, Bangalore

(i) Biosystematic studies on predatory coccinellidae

(a) Taxonomic studies

The species of the genus *Synona* were reviewed and the status of the Indian species confirmed. The species widely identified as *Synona melanaria* ab. *rougeti* was found to be distinct, requiring a new name. Based on the studies carried out, the genera *Nedina* and *Neojauravia* were synonymised with *Protothea* and *Pharoscymnus*, respectively. *Neojauravia naeida* was synonymised with *Pharoscymnus flexibilis*. *Sticholotis rugicollis* was found to be a distinct species and a new senior synonym of *S. gomyi*. Six species of *Nedina* were transferred to *Protothea* (Fig. 2).

One new species of *Halyzia* was recorded from Himalayan ranges of India and Nepal. The coccinellid collections at the National Museum of Natural History, Washington, DC, USA, were studied, with particular emphasis on the fauna of the Oriental region and the Indian subcontinent.

(b) Identification tools

Six species were added to the illustrated identification guide developed for common lady beetles of the Indian subcontinent and fact sheets in html/xml were developed for these species. About 50 new photographs and an illustrated account of the general morphology were added to the website (www.angelfire.com/bug2/j_poorani/index.html) on Indian coccinellids.

(c) New faunal records

Phrynocaria eberti (Nagaland) and *Ghanius karachiensis* (Karnataka, Tamil Nadu)

Fig. 2. ***Protothea quadripunctata*, a rare polymorphic lady beetle from Northeastern region**

Fig. 3. Asian multicolored lady beetle, *Harmonia axyridis*

were recorded for the first time from India. The immature stages of the tribe Shirozuellini were collected for the first time. The Asian multi-coloured lady beetle, *Harmonia axyridis* (Fig. 3) was recorded for the first time from India (West Bengal).

(ii) Biosystematic studies on Indian Tachinidae

The checklist of the family Tachinidae of the Indian subcontinent has 325 species under 163 genera, 33 tribes and 4 subfamilies. *Lophosia excisa* (Cylindromyiini) has been recorded on *Cyclopelta siccifolia* (Pentatomidae) from Shimoga and *Cylindromyia rufipes* (Cylindromyiini) on *Tolumnia* sp. (Pentatomidae) from Bangalore. *Chaetogena raoi*, *Drino* (*Palexorista*) sp. and *Exorista xanthaspis* were recorded parasitising *Amsacta albistriga*. Parasitism by *Carcelia illota* to an extent of 11% and *Goniophthalmus halli* up to 2% was recorded on *Helicoverpa armigera* on pigeonpea and lab lab. Parasitism by *Sturmiopsis inferens* was recorded to an extent of 5% on *Chilo partellus*.

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

Limited field release of the host specific stem gall fly, *Cecidochares connexa* was done against *Chromolaena odorata* in the GKVK campus of the University of Agricultural Sciences, Bangalore. There was a significant reduction in plant height, number of branches and panicles per plant and number of capitula per panicle due to the gall fly (Table 1). It had spread to a distance of 25 m in the north and 50 m in south, east and west directions from the release spot in the first generation. The second-generation galls were formed just below the inflorescence (Fig. 4), which resulted in less number of capitula per panicle.

It was observed that parasitisation of *Aleurodicus disperses* by *Encarsia gaudeloupae* was more active from September to January and reduced thereafter. Highest rate of parasitisation by the parasitoid on *A. disperses* (above 83.3%) was recorded on the host plant *Michaelia* sp. during November.

Fig. 4. Galls formed by *Cecidochares connexa* on *Chromolaena odorata*

Trichogramma brassicae was introduced for the biological suppression of *Plutella xylostella*. Initial screening revealed that *T. brassicae* parasitised highest per cent eggs of *Plutella xylostella* at four different dosages as compared to *T. chilonis* and *Trichogrammatoidea bactrae*. Further, interaction studies revealed that *Tr. bactrae* parasitised more (51.5%) than *T. brassicae* (48.5%) when both were simultaneously exposed to host eggs. *T. brassicae* gave higher per cent parasitisation when eggs were exposed first to *Tr. bactrae* (86%) or *T. brassicae* (95.2%) with 12 h gap, indicating that it is a dominant species over *Tr. bactrae*. However, with 24 h gap, the species exposed first gave higher parasitisation (Table 2).

Table 1. Impact of stem gallfly on *Chromolaena odorata* plant growth						
Parameter	Individual oviposition method			Mass oviposition method		
	Control	Treatment	% decrease over control	Control	Treatment	% decrease over control
Plant height 30 days after oviposition(cm)	173.72	154.26*	11.6	68.45	38.37*	40.8
Plant height 60 days after oviposition(cm)	207.89	173.14*	16.7	101.40	64.41*	36.5
Plant height 120 days after oviposition(cm)	-	-	-	167.70	74.77*	55.4
Mean number of branches per plant	25.55	16.45	35.6	11.35	3.91*	65.6
Mean number of panicles per plant	32.25	17.60	45.4	14.70	7.58*	48.4
Mean number of capitula per panicle	17.40	15.30	12.1	19.60	8.04*	59.0
Mean number of seeds per head	32.81	29.24*	10.9	-	-	-

*Student's 't' test significant @ 0.1 level

Table 2. Interaction studies of *Trichogrammatoidea bactrae* and *Trichogramma brassicae* in parasitising *Plutella xylostella*				
Species	Parasitization (%)	Adult emergence (%)	Per cent each species	
			Tr. bactrae	*T. brassicae*
Tr. bactrae alone	46.0	92.4	100.0	-
T. brassicae alone	55.3	94.1	-	100.0
Release of *Tr. bactrae* and *T. brassicae* simultaneously	62.8	86.1	51.5	48.5
Release of *Tr. bactrae* followed by *T. brassicae* with 12 h gap	53.0	91.0	14.0	86.0
Release of *T. brassicae* followed by *Tr. bactrae* with 12 h gap	37.6	96.0	4.8	95.2

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

(a) Evaluation of comparative performance of anthocorid predators *Blaptostethus pallescens* and *Cardiastethus exiguus* on *Sitotroga cerealella* infesting rice

When *Blaptostethus pallescens* nymphs were released in the ratio of 1: 5 (predator: host),

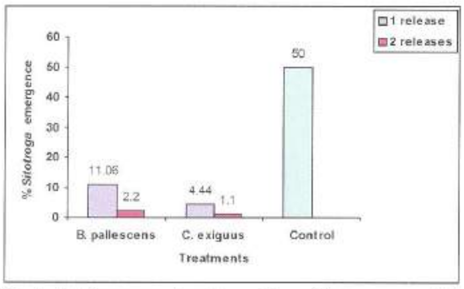

Fig. 5. Performance of anthocorids on *Sitotroga cerealella*

the emergence of *Sitotroga cerealella* infesting rice was 11.1 and 4.4 for 1 and 2 releases, respectively, whereas the corresponding figures for *C. exiguus* releases were 2.2 and 1.1%, respectively, while in the control 50% pest emergence was observed (Fig. 5).

(b) New anthocorid predator for the stored grain pests

A new anthocorid predator, *Xylocoris flavipes* was obtained from jowar storage bins. The predator consumed a total of 73.3 eggs of *C. cephalonica* during the nymphal stage with the highest number of fed on the 18th day (Fig. 6).

(c) Improvement in rearing of *Spodoptera exigua*

Attempts were made to improve the method of culture of *Spodoptera exigua*. Butter paper and wax paper were tried as oviposition substrates. Egg laying was almost equal on both substrates. Per cent hatching, however, was more in the case of the eggs laid on butter paper (67.8%) than those laid on wax paper (39.3%). In earthen pots and plastic containers, egg laying was 11.1 and 10.7 egg patches/female, respectively.

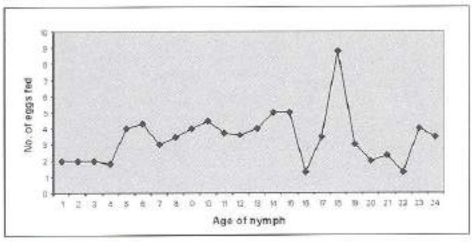

Fig. 6. Day-wise feeding of *Xylocoris flavipes* on the eggs of *Corcyra cephalonica*

(d) Use of kairomones to improve the production of *Campoletis chlorideae*

The possibility of utilizing kairomones to improve the production of *Campoletis chlorideae* was investigated. This experiment indicated that kairomones (larval wash of 7-day-old *Spodoptera litura*) could be effectively used to improve the production of *C. chlorideae* (Table 3).

Table 3. Use of kairomone to improve the production of *C. chlorideae*

Parameter	Kairomone treated	Control
Parasitism (%)	40.2	25.0
Number of cocoons per exposure	21.3	11.4
Number of adults per cage	12.9	7.4
Number of females per cage	4.7	3.0

(e) Rearing of *Campoletis chlorideae* in walk-in chambers

Campoletis chlorideae was reared in walk-in chambers set at 26±2°C and 70±2% RH. The mean per cent parasitism recorded was 36.6, 31.6 and 24%, respectively, during January, February and March, respectively, in comparison with 40.5, 25.9 and 9.5 %, respectively, in normal lab conditions (when humidity was extremely low – 50±5%). Female progeny production was markedly improved by rearing in walk-in chambers. It is thus evident that during the dry months, continuous maintenance of *C. chlorideae* is possible by rearing in controlled conditions.

(f) Storage of *Telenomus remus* egg cards

The storability of parasitised egg cards of *Telenomus remus* was investigated to arrive at the optimum age for storage and the optimum duration of storage and thus to plan their shipment. Eggs of 3-5 and 8-10-days-old were not amenable to storage at 15±2°C, as adult emergence after removal from storage was very low. Six to eight-day-old eggs could be stored for up to 10 days with 89.5% emergence. The mean developmental period also increased to 16 and 19 days, respectively, while the normal developmental period is 10-12 days.

(g) Feeding preference of anthocorids on parasitised and unparasitised eggs

The feeding preference of two anthocorid predators, *Orius tantillus* and *B. pallescens* on parasitised and unparasitised eggs of *C. cephalonica* and *Helicoverpa armigera* was studied. Results of choice and no-choice tests showed that there was significantly higher preference for unparasitised eggs in comparison to parasitised eggs. The preference for unparasitised eggs of *H. armigera* over parasitised eggs (Table 4) indicates that it may be possible to integrate releases of anthocorids and trichogrammatids for biololgical control of lepidopteran pests/sucking pests in different crop ecosystems.

Table 4. Feeding preference of *Orius tantillus* and *Blaptostethus pallescens* on unparasitised and parasitised eggs of *Helicoverpa armigera*

Anthocorid predators	Mean (±SEM) number of eggs fed *			
	No choice test		Choice test	
	Unparasitised	Parasitised	Unparasitised	Parasitised
O. tantillus nymph	9.3 ± 0.6 (46.6)*	0.3 ± 0.3 (1.6)	10.3 ± 2.1 (51.6)	0.3 ± 0.3 (1.6)
O. tantillus adult	8.0 ± 1.5 (40.0)	0.0 ± 0.0 (0.0)	5.6 ± 0.8 (28.3)	0.6 ± 0.3 (3.3)
B. pallescens nymph	20.0 ± 0.0 (100.0)	0.3 ± 0.3 (1.6)	13 ± 4.4 (65.0)	0.7 ± 0.3 (3.3)
B. pallescens adult	16.6 ± 1.6 (83.3)	0.6 ± 0.3 (3.3)	13 ± 1.7 (65.0)	0.7 ± 0.3 (3.3)

Values in parentheses are per cent eggs fed; * Differences between the means of parasitised and unparasitised significant (*P*=0.05) in all cases

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

(a) Biology of *Sitotroga cerealella* on different grain medium

Irrespective of the grains used for rearing, the egg, larval and pupal period of *Sitotroga cerealella* ranged between 5.1-8.1, 15.7-24.1, 7.6-10.2 days, respectively. Total average life cycle ranged from 37.8 to 39.0 days. Maximum average fecundity was obtained on maize (129.6 eggs/female) followed by paddy (119.9 eggs/female). The average total life cycle was completed faster during October (32.2 days), whereas it took longest in January (39.9 days).

(b) Mass multiplication of *S. cerealella* on unhusked wheat

Sitotroga cerealella is being reared on a large-scale on unhusked wheat in the laboratory and the culture is in the 18th generation. The oviposition period lasted for four to five days but the maximum oviposition the i.e. 80-90% of total number of eggs were during the first three days of oviposition period. Temperature below 28 °C was not favourable for egg production. The moths could be reared at 30 °C to get continuous supply of eggs.

(c) Rearing of *Cryptolaemus montrouzieri* on *S. cerealella* eggs

Twelve generations of *C. montrouzieri* were reared on *S. ceralella* eggs. Eggs exposed to UV were provided to one-day-old *C. montrouzieri* larvae. Three cc of *S. cerealella* eggs were used for rearing 10 larvae of *C. montrouzieri* up to pupal stage. Results during these generations indicated that pupation was 65.8% and adult emergence from these pupae was 82%. Average total survival was 58.5%. Average larval and pupal periods were 14.9 and 7.0 days, respectively, whereas adult longevity was 41.0 days. Average adult weight was 8.0 mg.

(d) Fabrication of oviposition cage and moth collection device for *S. cerealella*

A new low cost device for moth collection was designed and fabricated which had advantages like no disruption of the larval rearing regime; collection of moths directly in oviposition cage with least adult handling and facilitating daily replacement of adult oviposition cage.

An oviposition cage for *S. cerealella* was designed and fabricated which had special advantages like least adult handling; supply of honey and water from outside to avoid moth escape; to get eggs free from contamination by scales; removing oviposition substrates without opening the lid and collection of eggs.

(vi) Mass production and evaluation of *Micromus igorotus*

(a) Host range of *M. igorotus* and larval feeding potential

The larvae of *M. igorotus* survived and pupated on all the eleven species of aphids provided and maximum pupation occurred with the use of the bamboo woolly aphid, *Pseudoregma bambusicola*. However, it could not survive on other homopteran insects like mealybugs (three species), whiteflies (two species) and a psyllid. The larvae failed to survive on eggs of two lepidopterans.

Irrespective of instars of the aphid species, *A. craccivora* was fed upon significantly in higher number (680 aphids/larva) as compared to *C. lanigera* (510 aphids/larva). Regardless of species of the aphids, it was first instar, which was fed upon in maximum numbers (688 aphids/larva).

Pre-oviposition period on different aphid species ranged from 4.3 to 6.3 days and was significantly longer when adults were reared on *A. gossgpii*. However there was no significant difference in pre-oviposition period when adults were fed with other species. The predator laid maximum number of eggs when reared on *P. bambusicola* (799.9 eggs / female) while it was the least when *C. lanigera* was used as host (590.2 eggs / female). There was no significant difference in the fecundity obtained on *A. gossypii* (654.4 eggs/female) and *A. craccivora* (662.2 eggs/ females). The predators laid 35.5% times more number of eggs when *P. bambasicola* was used as prey as compared to *C. langiera*. Per cent increase in fecundity was 12.2 and 10.9% on *A. craccivora* and *A. gossypii*, respectively, as compared to *C .lanigera*.

First, Second and third instar larvae of *M. igorotus* fed on 63.8, 112.7 and 283.0 *C. lanigera*. The corresponding values on *A. craccivora* were 41.6, 115.0 and 354.7 aphids. This shows that consumption increased with advancement of age of the larvae on both the hosts. When *C. lanigera* was used as host, 61.6% of total aphids consumed were fed in the last instar while in the case of *A. cracivora*, 69.4% of total aphids consumed were fed in third instar.

The egg period of *M. igorotus* varied from 3.7 to 4 days and it did not vary significantly when adults were fed with different species of aphids. Similarly, there was no significant difference in larval period (6.7 to 7.5 days) when different aphids were provided as host. Pupal period however varied significantly, being longer on *A. craccivora* (7 days) and *A. gossypii* (7 days) and shortest on *C. lanigera* (6 days).

(b) Rearing of *Dipha aphidivora*

The predatory lepidopteran, *Dipha aphidivora* could successfully be reared on frozen aphids. The larval period was marginally extended by 2 to 3 days. Reduction in pupation was noticed from 64 to 52 per cent. Reduction in adult emergence was noticed from 87 to 72 per cent while adult longevity was marginally affected. The mean fecundity of *Dipha* reared on frozen aphids was also lower (Table 5).

Dipha aphidivora was found to be capable of completing its life cycle on the two- tailed-mealybug, *Ferrisia virgata*. The larvae of *D. aphidivora* fed on crawlers in the mealybug colonies and did not feed on the mature females.

Table 5. Rearing *Dipha aphidivora* on different hosts

Parameter	Sugarcane woolly aphid		*Ferrisia virgata*
	Frozen SWA	Fresh SWA	
Adult emergence (%)	72	87	27.8
Mean adult longevity (days)	5.7	7.2	7.8
Mean fecundity	20	24	12.8
Hatchability (%)	80	80	78.9
Pupation (%)	52	64	-
Egg to adult (days)	28	25	-

(vii) Herbivore induced plant synomones and their utilization in enhancement of the efficiency of natural enemies

Volatile organic compounds (VOCs) were trapped, isolated and identified from Fern, *Chenopodium* sp. and *Ocimum sanctum*. Twenty-eight compounds were identified from fern leaves and the major fractions were: trans, trans-2, 4-decadienal, tetradecenal, tetradecanoic acid, hexadecanal, 2-methyl, heneicosane, octodecanoic acid, 9,17-octadecadienal and muskolectone. In *Chenopodium* sp. most common compounds were plant hydrocarbons. However, main VOCs of *O. sanctum* leaves were: citral, methyl eugenol, methyl chavicol, β-caryophyllene and α and β-bisabolene.

A mixture of four plant volatiles, i.e. pentacosane + tricosane+heptacosane+octocosane in the ratio of 1: 3:1:1 at 50% concentration was attractive to 4-day-old *Chrysoperla carnea* adults as indicated by mean Excess Proportion Index.

Eleven plant volatile compounds bioassayed for their activity against *C. carnea* at six different concentrations revealed that ten of them are effective at 0.05 and 0.1% concentrations.

Corcyra cephalonica eggs conditioned to *H. armigera* and *S. litura* pheromones for one hour and then exposed to *T. chilonis* adults for parasitisation showed preference to *H. armigera* lure, which resulted in 99.5% higher parasitisation over control.

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

In the field experiment conducted at the Regional Station (University of Agricultural Sciences), Raichur, on the use of kairomones along with the supplementary food as reinforcing agent for chrysopid predators, the number of predators were more and the damage was less in the kairomone-treated plot. In another field experiment recovery of *T. chilonis* was more in the kairomone-treated plot compared to control. The yield and number of good open bolls were more in the kairomone-treated plot. The kairomonal formulation was tested for efficacy to increase the abundance of *Trichogramma japonicum* against stem borer of rice. The white ear head incidence was significantly lower than other treatments though there was no change in the yield. In an attempt to increase the shelf-life of the kairomone formulations, butylated hydroxy toluene and butylated hydroxy aniline were used as stabilizers. However, there was no significant difference between the compounds at the concentration tested, though the kairomone stored at the frozen conditions showed shelf-life of 15 days. The parasitising efficiency of *T. chilonis* was not affected by the color of the septa used.

Methyl salicylate was recorded as one of the attractants to several species of predators. Plants exposed to methyl salicylate for 24 and 48 hours recorded more oviposition by *C. carnea*. However, there was no significant orientational response in case of *Cheilomenes sexmaculata* and *Cardiastethus exiguus* exposed to methyl salicylate.

None of the compounds tested evoked any ovipositional response in *C. montrouzieri*. Among the cultivars, MCU-5, MCU-9 and MCU-7 treated with the kairomone-impregnated septa recorded more parasitisation by *T. chilonis*. There was significant increase in the parasitisation of *H. armigera* by *C. chlorideae* on plants provided with kairomone-treated septa.

(ix) Development and evaluation of improved strains of trichogrammatids, *Cheilomenes sexmaculata* and *Chrysoperla carnea* tolerant to insecticides and temperature with high host searching ability

(a) Comparative efficacy of *T. chilonis* adapted to low temperature

A low temperature-adapted strain was developed by rearing *T. chilonis* at temperature of 18°-24°C for 30 continuous generations in insect rearing cage (30 cm^3) with 95.0±0.44% parasitism. The development, searching ability and biological parameters of adapted strain of *T. chilonis* for 18°C temperature was studied in comparison with the laboratory population. Non-significant variation among adapted and non-adapted strain was observed with respect to per cent parasitism, fecundity and longevity when reared in small glass vials. However, in the cage studies for searching ability, 58% eggs were parasitised by the low temperature adapted-strain as compared to 17.2% by the non-adapted strain. The host-searching test indicated that adaptation at low temperature leads to better host searching and such strain can be successfully utilized under a low temperature regime (Table 6).

(b) Development of high quality strain of *T. chilonis* with better host searching and high fecundity

A high quality strain of *T. chilonis* (HQS-Tc) was developed in the laboratory by altering the rearing system. Selection of parasitoids for 45 generations in 1-m^3 cages, gave consistent parasitism of ≥95%. The fecundity and sex ratio were ≥80 and ≥70% females compared to fecundity of ≥45 and sex ratio of 45% females in the laboratory population (LP-Tc). The females of HQS-T_c lived for 10 days as compared to 7 days of the LP-Tc. The per cent egg parasitism by HQS-Tc was significantly more, 36.6-325.0% compared to LP-Tc in different parasitoid release rates. The HQS-Tc retained its superior traits for 10 generations in the laboratory (Fig. 7).

Table 6. Biological parameters of *Trichogramma chilonis* adapted to low temperature (18-24°C)

Strain	In glass vials (15x2.5 cm)				Cage study (30cm^3)
	Parasitism (%)	Developmental period (days)	Fecundity	Longevity (days)	Searching ability (% parasitism)*
Adapted	51.9	14.0	41.3	5.4	58.0
Non-adapted	66.5	12.0	48.2	4.9	17.2

* Differences between the means significantly different (P=0.05) by LSD

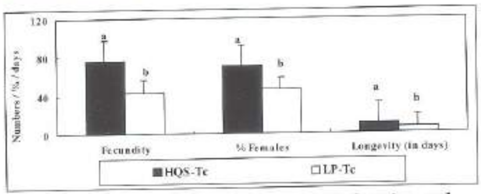

Fig. 7. Enhanced fecundity, per cent females and longevity (±SE) of HQS-Tc (a) and LP-Tc (b) (Values are mean of 6 generations after developing high quality strain. Bar showing different letters are significantly different P = 0.05)

(c) Molecular characterization of trichogrammatids

The DNA from various *Trichogramma* species was isolated and spectrophotometer absorbance at A_{260}/A_{280} indicated the ratio of 1.9. Yield of up to 4ìg of DNA was obtained from 100 adults. The isolated DNA was found to be suitable for down stream applications such as PCR and RAPD-PCR. An amplification of 600bp and 550bp was observed using ITS-1and ITS-2 primers, respectively. Sequenced ITS2 region of 7 species/ strains of trichogrammatids and deposited with GenBank with accession nos. DQ220703 (*T. chilonis*), DQ314611 (*T. brassicae*), DQ381281 (*T. brasiliense*), DQ381280 (*T. evanescens*), DQ381279 (*T. mwanzai*), DQ344045 (*T. dendrolimi*), DQ344044 (*T. embryophagum*).

(d) Determination of biochemical and genetic mechanisms in strains of *T. chilonis*

The GST - Conjugative activity in laboratory susceptible strain was significantly lower than that of pesticide-tolerant (endosulfan, monocrotophos and fenvalerate) strains. Highest activity was measured in multiple insecticide-tolerant strain (MITS) followed by endosulfan, monocrotophos and fenvalerate-tolerant strains. MITS recorded 2.13-fold increase in activity, while endosulfan, monocrotophos and fenvalerate-tolerant strains showed 1.7-fold increase in activity compared with laboratory susceptible strain. The carboxyl esterase activity increased 1.18-fold in monocrotophos-tolerant strain. However, there was a decreased activity in fenvalerate and endosulfan-tolerant strains as well as MITS.

The LC_{50} values of tolerant strain for three insecticides, *viz.* endosulfan, monocrotophos and fenvalerate were 1075, 702.3 and 73 ppm and corresponding LC_{50} values for susceptible population were 70.9, 345.2 and 26 ppm. The resistance factor was 15.2, 2.0 and 2.8 times over susceptible population for endosulfan, monocrotophos and fenvalerate, respectively. The MITS was incomplete dominant for tolerant female progeny as values obtained were +0.30 to +0.85 and recessive for tolerant males –0.05 to –0.30 for three insecticides. Crossing with tolerant parent increased the tolerance to and degree of dominance, for both males and females showed incomplete dominant gene involvement.

(e) Field evaluation of multiple insecticide tolerant strain (MITS) against *H. armigera* on tomato in Malur taluk (Bangalore) in farmer's field

The results indicated that releases of MITS gave egg parasitism of 34.1% and it was significantly higher as compared to egg parasitism recorded in laboratory strain released plot (LSP) or natural parasitism in farmers' practice plot (FPP). Number of larvae per plant (0.7 / plant) and per cent fruit bored (2.4%) in MITS + FPP plots were also significantly lower as compared to LSP + FPP or FPP. The yield recorded in MITS + FPP plots was 30.0 and 47.8 q more than LSP + FPP and FPP plots, respectively.

(x) Development and formulation of artificial diets for the rearing of coccinellids and anthocorids

Females of *Orius tantillus* were found to lay eggs (11 eggs/female) and survived for 10 days on the refined artificial diet (AD) based on soybean hydrolysate and yeast extract. Fecundity of *O. tantillus* on old beans (6-8 days old) was significantly higher (6 eggs/female) than young beans (1-3 days old; 1.7 eggs/female). Populations of *C. montrouzieri* collected from Pune were reared on beef liver-based artificial diet and compared with population of PDBC. Pupation and survival of the predator on artificial diet were 59, 57 (PDBC); 58.5 and 56.2 (Pune), respectively. There was no significant difference in larval and pupal periods, pupation (%) and adult emergence (%) between *C. carnea* reared on artificial diet or on *Corcyra* eggs from F39 to F46 generations (Table 7). There was no significant difference on biological attributes between AD and *Corcyra*-reared *C. carnea*.

Table 7. Biological parameters of *Chrysoperla carnea* reared on artificial diet and *Corcyra* eggs

Parameter	Artificial diet	*Corcyra* eggs
Pupation (%)	83.7	82.8
Adult emergence (%)	79.0	81.3
Fecundity (eggs/female)	341.0	359.0
Longevity (days)	50.2	50.0

(xi) Evaluation of Artificial diets for *Opisina arenosella* and *Plutella xylostella*

(a) *Opisina arenosella*

The refined semi-synthetic diet with toddy palm leaf powder in combination with defated soy and kabuligram improved the biological parameters (larval survival, per cent pupation and fecundity) and was on par with that of the host reared on natural diet (coconut leaves). The refined diet had 76.2% pupation and 68.4% adult emergence. The shelf-life of the artificial diet at room temperature (25-27°C) was 22 days. The cost of rearing a pupa on the artificial diet based on per cent pupation (76.2) worked out to Re. 0.78, while on the natural diet (coconut leaves) the cost was Rs.0.71 (91.4% pupation). Artificial diet stored under refrigerated conditions for 30 days provided 60.2% pupation.

The late larval parasitoid, *Goniozus nephantidis* and pupal parasitoid, *Brachymeria nephantidis/B.nosatoi* successfully completed the development on the artificial diet reared host.

(b) *Plutella xylostella*

The soy-based diet with cabbage leaf powder was refined to have the biological parameters on par with that obtained on natural host (mustard seedlings). A pupation of 62.6%, adult emergence of 56.4% and fecundity of 76.6 was obtained on the artificial diet compared to those reared on mustard seedlings (86.2, 82.2 and 118.2, respectively). The shelf-life of the soy-based diet at room temperature (25-27°C) was 18 days. Based on the percentage pupation of 62.6%, the cost of rearing a pupa on the artificial diet worked out to Re. 0.38 and on the natural host (mustard seedlings) it was Rs.0.26 per pupa for 86.2 per cent. The artificial diet stored at refrigerated conditions (5°C) for 30 days recorded 56.2% pupation.

The development of *C. plutellae* on the artificial diet-reared host was compared with that of the host reared on mustard seedlings. Significant differences were observed in the percentage parasitisation and adult longevity between the parasitoids reared on the artificial (78.4% and 8.12 days, respectively) and natural diet-reared hosts (92.6 % and 12.4 days, respectively).

(c) *Spodoptera exigua*

The pest was reared on the semi-synthetic diet for 18 generations. The development period was, however prolonged on the artificial diet. The per cent pupation and adult emergence was 78.6 and 75.3, respectively, on the artificial diet, which differed significantly with that reared on natural host (castor leaves) control values.

(d) *Zygogramma bicolorata*

A semi synthetic diet was formulated based on the diets prescribed for other chrysomelids. Leaf extract of *Parthenium hysterophorus* was added to the diet for rearing the beetle. The grub survival and pupation when reared on the artificial diet was 48.2 and 36.4%, respectively, compared with 90.6 and 83.2% when reared on parthenium plants.

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

(a) *Helicoverpa armigera* NPV

Laboratory studies were conducted to evaluate the efficacy of different adjuvants in increasing the larval mortality in second instar *H. armigera* larvae.

Even though all the adjuvants screened significantly increased the larval mortality, four adjuvants, *viz*., soybean flour (10%), Tinopal (0.2%), molasses (5%) and CSKE (10%) along with *Ha*NPV resulted in more than 85% larval mortality. This was followed by boric acid (1.0%) and turmeric (2%) with larval mortality of 82.3% and 74.4%, respectively.

(b) *Spodoptera litura* NPV

Laboratory studies were conducted to evaluate the effect of different adjuvants in increasing the efficacy of *Spodoptera litura* NPV

(*Sl*NPV). Different adjuvants along with *Sl*NPV were exposed to the simulated sunlight in the sun test machine. After exposing the virus to irradiation of 500W/m² bioassays were conducted and the larval mortality was recorded.

Among the different adjuvants tested Tinopal (0.1%) gave the maximum larval mortality of 81.8% as compared to 39.2% larval mortality of irradiated *Sl*NPV without any adjuvant. This was followed by cotton-seed kernel extract (CSKE) (10%) where 65.2% larval mortality was recorded, which was statistically on par with jaggery (5%) and molasses (5%). A combination of the adjuvants was also evaluated for efficacy in increasing the larval mortality in second instar *S. litura* larva (Table 8). These adjuvants along with SlNPV were exposed to an irradiation of 500 W/m² using sun test machine for 90 minutes.

In another experiment, all the adjuvant combinations enhanced the larval mortality, significantly. The mortality data revealed that the combination of *Sl*NPV + CSKE (62.5%) + corn oil (1.5%) + crude sugar 25(%) + Tween (0.04%) was the most effective in increasing the mortality due to *Sl*NPV (95.2%). This combination of adjuvants is same as that of the commercial adjuvant called Coax (Traders Oil Mill Co., Texas, USA). This was followed by *Sl*NPV + Soya flour (8%) + Soya oil (5%) + crude sugar (5 %) + Trinton (0.01%) and *Sl*NPV + CSKE (10%) + Tinopal (0.01%) + Tween (0.04%) resulting in a larval mortality of 89.5% and 84.4%, respectively (Table 9).

(xiii) Evaluation of fungal pathogens against onion thrips (*Thrips tabaci*)

Results of field experiment revealed that *Beauveria bassiana* and *Verticillium lecanii* isolates marginally reduced the population of *T. tabaci* on onion. But only Bb1 and Bb6 recorded significantly higher yield than control. Carbosulfan was however, more effective than the fungal pathogen (Table 10).

Table 8. Efficacy of different adjuvants as UV protectants for *Sl*NPV against second instar larvae of *Spodoptera litura*

Treatment	Larval mortality (%)
*Sl*NPV + soybean flour (10%)	50.0[d]
*Sl*NPV + starch (5%)	43.5[d]
*Sl*NPV + maize flour (10%)	43.5[d]
*Sl*NPV + Tinopal (0.1%)	81.8[b]
*Sl*NPV + molasses (5%)	59.1[c]
*Sl*NPV + CSKE (10%)	65.1[c]
*Sl*NPV +jaggery (5%)	59.1[c]
*Sl*NPV alone	39.2[e]
Non-irradiated *Sl*NPV	88.4[a]

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

Table 10. Efficacy of fungal pathogens against onion thrips

Treatment	Per cent decrease in thrips population over control	Marketable yield (t/ha)
Bb-1	20.2	25.1[b]
Bb-5a	17.7	24.1[bc]
Bb-6	22.9	24.8[b]
Vl-1	16.0	23.2[bc]
Vl-6	14.8	21.8[bc]
Vl-7	12.2	21.9[bc]
Bb-1+ Imidacloprid	17.0	24.4[b]
Vl-7 + Imidacloprid	13.9	24.8b
Carbosulfan	96.9	29.2[a]
Control	-	20.8[c]

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

Table 9. Efficacy of adjuvants as UV protectants for *Sl*NPV against second instar larvae of *Spodoptera litura*

Treatment	Larval mortality (%)
*Sl*NPV + CSKE (10%) + crude sugar (10%) + Tween (0.04%)	74.1[c]
*Sl*NPV + CSKE (5%) + crude sugar (10%) + Tween (0.04%)	56.0[d]
*Sl*NPV + CSKE (62.5%) + corn oil 1.5% + crude sugar 25% + Tween (0.04%)	95.2[a]
*Sl*NPV + Soya flour (8%) + Soya oil (5%) + crude sugar (5 %) + Trinton (0.01%)	89.5[b]
*Sl*NPV + Soya flour (7.5%) + Soya oil (1.5%) + corn flour (7.5%) + corn oil (5 %)	70.3[c]
*Sl*NPV + CSKE (10%) + Tinopal (0.01%) + Tween (0.04%)	84.4[b]
*Sl*NPV alone	41.3[e]
Non-irradiated *Sl*NPV	88.5[b]
Means followed by similar letters are not significantly different (P=0.05)	

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

Six isolates of *Hirsutella thompsonii* var. *synnematosa* were grown on PDA and the radial growth was recorded. The maximum growth of 64.3 mm with a growth rate of 1.95 mm/day was observed in MF(Ag)32 while MF(Ag)27 recorded the minimum growth and growth rate of 51.17 mm and 1.51 mm/day, respectively, at the end of 30 days of incubation.

Conidial production of *H. thompsonii* var. *synnematosa* varied significantly among the isolates. At 18 mm diameter MF(Ag)28 produced 6.7 times more conidia than those produced by MF(Ag)27 in the same diameter. Conidial germination increased over time in all isolates. This increase was most rapid after 1 h of preparation of the conidial suspension. There were no major differences among the isolates in micromorphology.

The isolates of *H. thompsonii* var. *synnematosa* differed in terms of synnemata characteristics. MF(Ag)28 yielded the maximum number of mature synnemata. In MF(Ag)27, 3 buds were seen on the 25th day which did not elongate to attain maturity till the end of the experiment. Branching of synnemata was observed only in one isolate, i.e. MF(Ag)31 (Fig. 8).

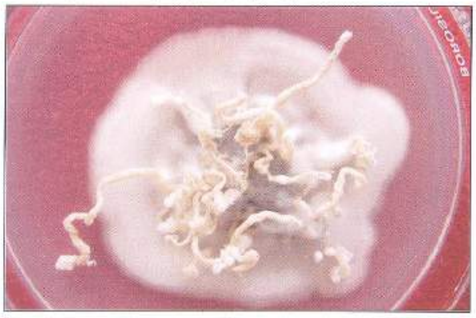

Fig. 8. ***Hirsutella thompsonii* var. *synnematosa* [MF(Ag)31]**

In the experiment conducted to assess the effect of different surfactants (Triton X-100, Tween 80, Tween 60 and Tween 40) on the biomass characteristics of *H. thompsonii*, Tween 80 excelled in terms of the parameters tested including the number of CFU, pellet number, wet and dry weights but not the pellet size. The numbers of CFU obtained with Tween 80 was 2.4 times more than that produced in control (unamended). Triton X-100 produced the lowest numbers of CFU, pellet size, pellet number, and wet and dry weights.

A new liquid medium based on tomato was developed to find out if it can replace the commonly used potato dextrose broth for the mass production of *H. thompsonii*. A very significant increase in the CFU was observed when 2% dextrose was used.

In mass production studies on *H. thompsonii* folic acid at the concentration of 200 µg/l recorded the maximum numbers of CFU, a 2.9-fold increase followed by 100 µg/l concentration which showed 2.6-fold increase over control. The 200 µg/l concentration also recorded the maximum wet and dry weights.

Though biotin could not bring about significant increase in growth parameters, it was able to increase conidial production in *H. thompsonii* especially at the maximum concentration tested, i.e. 7.5 µg/l. Biotin had no influence on the germination of conidia of *H. thompsonii* obtained from the vitamin-amended medium. As observed in the case of radial growth, the micromorphology of the test fungus was also not influenced by biotin at any concentration tested.

Tetranychus urticae eggs treated with the exudate from sporulating culture *H. thompsonii* showed very significant reduction (64.6%) in hatching (Table 11). The exudate exhibited ovicidal effect through desiccation in up to 28 per cent of the eggs. A significant number (38%) of treated eggs remained unhatched even after 4 days of incubation, compared with control (4%).

Table 11. Effect of *Hirsutella thompsonii* exudate on the hatching of *Tetranychus urticae* eggs

Treatment	Hatching (%) (±SEM) of eggs after (days)			
	1	2	3	4
Exudate	0.0	4.0±2.45	24.0±10.30	34.0±13.64
Control	0.0	36.0±9.27	74.0±7.48	96.0±2.45
't' value	NS	3.83**	3.53**	6.49***

**Highly significant (P=0.01); ***Very highly significant (P=0.001); NS: Not significant

The exudate showed toxicity to nymphs of *T. urticae* that were fed on treated cowpea leaves. A maximum of 33.3 per cent mortality was obtained in nymphs before they turned into adults. In the fecundity test, an adult female feeding on exudate-treated leaf could lay only 30.7 eggs compared with 51 eggs laid by the mite feeding on untreated leaf over a period of 7 days. Hatching of those eggs was also lower (18.5%) in comparison with control (38.3%).

The effect of *H. thompsonii* in combination with different stickers, namely, carboxy methyl cellulose (CMC) and gum acacia was assessed on okra. CMC recorded 93.5 and 95.29% mite mortality after the 1st and 2nd sprays, respectively.

The effect of three fungi, viz. *Beauveria bassiana*, *Lecanicillium lecanii* and *L. psalliotae* against *T. urticae* on okra was assessed under greenhouse conditions. More than 50% mite mortality was observed when CMC was added in the spore suspension after three days of application in all the treatments including control. *Beauveria bassiana* recorded the highest mortality of 60.82% and 39.94% as against control plants, which recorded 57.34 % and 31.37 % in CMC treated spore suspension spray at the end of 3rd and 12th day respectively. Mortality, however, showed a sharp decline when spore suspension was used without CMC. In the second trial, *B. bassiana*, *L. lecanii* and *L. psalliotae* recorded 100% mite mortality after 3 days of spraying of CMC treated spore suspension, which reduced to 38.90, 53.58 and 37.37 %, respectively, after 18 days of spraying.

In the greenhouse trial on *H. thompsonii*, *B. bassiana* and *L. lecanii* against *T. urticae*, up to 50 % mortality was achieved on rose.

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

Trichoderma harzianum

Twenty-eight isolates of *T. harzianum* were tested for their antagonistic potential against *Phytophthora parasitica* var. *nicotianae* in dual culture. On the third day after inoculation, isolates Th-6 (6.0 cm) and Th-15 (5.99 cm) showed faster growth, followed by the isolates, Th-2, Th-3, Th-9, Th-18. The isolates Th-11 and Th-16 were slower in growth (3.21cm, 3.51 cm, respectively). The per centage reduction in *P. parasitica* var *nicotianae* was very high in isolate Th-9 (57.32%) followed by the isolates Th-5, Th-GTH7, Th-1, Th-2, Th-3, Th-8, Th-7, Th-21, Th-ITCC, Th-12 and Th-CPCRI (reduction percentage - 54.39 to 50.08).

The *T. harzianum* isolates were tested for their ability to utilize glucan present in the amended media as sole carbon source. The isolates Th-11, Th-Kallangai, Th-6, Th-1, Th-Kudlu and Th-GTH7 showed better growth than the remaining isolates. The isolates Th-10 and Th-5 showed slower growth among all the isolates. However, on fifth day, all the isolates covered the entire Petri dish (9.0 cm) except Th-5 (8.6 cm). On *Phytophthora* cell wall-amended medium after third day of inoculation the isolates Th-CICR, Th-Kallangai, Th-15, Th-ITCC, and Th-13 showed very good growth (diameter ranges from 5.94 cm to 5.0 cm) followed by the isolates Th-P26, Th-3, Th-9, Th-11, Th-6 and Th-Kudlu. On carboxy methyl cellulose-amended media, on third day after inoculation very less growth was observed when compared to other two solid media (PpnCWAM and PDA). The isolates Th-Kallangai and Th-12 showed faster growth (4.53 cm and 4.45 cm) than the isolates Th-CICR, Th-8, Th-15, Th-Kudlu, Th-9, Th-P26, Th-3 (4.29 cm to 3.89 cm). The isolates Th-21 and Th-14 showed poor growth (2.28cm and 2.13cm respectively). On the fifth day, isolates Th-3, Th-6, Th-8, Th-12, Th-13 and Th-19 covered the entire plate. Th-14 showed slow estgrowth among all the plates.

On carboxy methylcellulose broth (0.2%), the growth of Th-10 was high (0.570 g/100ml) in terms of mycelial dry weight (including the unutilized CMC) after 7 days in shaker culture followed by the isolates Th-12 (0.520 g/100 ml), Th-GTH7 (0.483 g/100 ml), Th-Varansi (0.366 g/100ml) and Th-13 (0.335 g/100 ml).

Twenty-eight isolates of *T. harzianum* were tested for their ability to produce glucanases in *P. parasitica* cell wall-amended liquid medium. Among all isolates Th-11 showed maximum endo 1,4- glucanase activity when grown on CMC media (1.7472 A_{500}/ml) followed by Th-14 (1.2512 A_{500}/ml) and Th-15 (1.176 A_{500}/ml) (Fig. 9). In the isolates Th-1, Th-2, Th-4, Th-ITCC and Th-Kudlu, the enzyme activity could not be detected. Th-GTH7 showed maximum activity when grown on Ppn CWAM followed by Th-13 (1.264 A_{500}/ml), Th-11 (0.752 A_{500}/ml), Th-12 (0.7392 A_{500}/ml). In the isolates such as Th-1, Th-6, Th-18, Th-ITCC, Th-Varanasi, the enzyme could not be detected. Th-5 showed maximum b-1,3- glucanase activity when grown on CMC broth (2.24 A_{500}/ml) followed by isolates Th-18 (1.344 A_{500}/ml), Th-P26 (1.272 A_{500}/ml) and Th-12 (0.928 A_{500}/ml). The isolate Th-19 showed very poor activity among all isolates (0.024 A_{500}/ml). Th-Kallangai showed maximum b-1,3-glucanase activity when grown on Ppn- CWAM (2.64 A_{500}/ml). Th-14 (2.424 A_{500}/ml), Th-1 (1.944 A_{500}/ml), Th-6 (0.9184 A_{500}/ml), Th-8 (0.816 A_{500}/ml) also showed better activity. Th-19 showed very poor activity (0.016 A_{500}/ml). In the isolates Th-CPCRI, Th-Kudlu, Th-13 and Th-11, the enzyme activity could not be detected (Fig. 10).

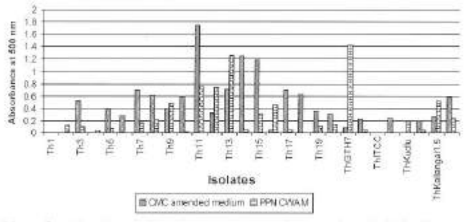

Fig. 9. Endo 1,4 glucanase activity in *Trichoderma harzianum* isolates

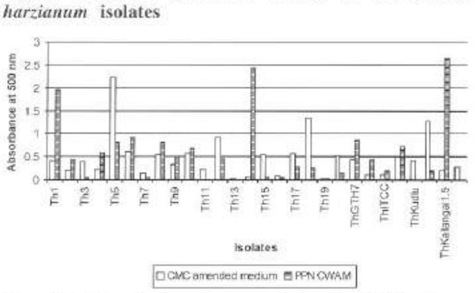

Fig. 10. β-1, 3 glucanase activity in *Trichoderma harzianum* isolates

Trichoderma virens

Fourteen isolates of *T. virens* were screened against *Sclerotium rolfsii, Macrophomina phaseolina, Rhizoctonia solani* and *Fusarium ciceri*. From the dual plate cultures up to 10 days of observation, the following isolates were found to be highly antagonistic.

TVS3, TVS5, TVS7, TVS8, TVS12 and TVS-CICR - against *S. rolfsii,*

TVS5, TVS8, TVS12, TVS-ITCC and TVS-CPCRI – against *F. ciceri,*

TVS4, TVS5, TVS7, TVS11 and TVS12 against *R. solani* and

TVS4, TVS5, TVS9 and TVS12 – against *M. phaseolina.*

The colony diameters of the *Trichoderma* isolates on *S. rolfsii* cell wall- amended medium ranged between 5.7 cm for Tv18 and 1.5 cm for Tv36 and between 6.4 cm for Tv3 and 1.2 cm for Tv36 on CCAM. The diameters of the colonies of *T. viride* isolates on PDA on the third day after inoculation, ranged between 2.2 cm (Tv36) and 8.6 cm (Tv3) and was uniformly 9 cm for all isolates except Tv36, which had a colony diameter of 3.4 cm, on the fifth day after inoculation. The diameters of the isolates grown on SrCWAM, on the third day were between a minimum of 2.3 cm (Tv13) and a maximum of 5.8 cm (Tv16). On the fifth day after inoculation, the colony diameters of the isolates on SrCWAM, were in the range of 3.5 cm (Tv36) and 9 cm (Tv11). The colony diameters of the isolates on CCAM, on the third day after inoculation, was a minimum of 2.4 cm (Tv25) and a maximum of 6.4 cm (Tv3), whereas on the fifth day after inoculation, the diameters were found to be in the range of 3.3 cm (Tv36) to 9.0 cm (Tv4, Tv8, Tv11 and Tv12).

Exochitinase and endo chitinase activities in the *T. viride* cultures were studied by growing them on the colloidal chitin-amended medium. Exochitinase activity was high in the isolates Tv3, Tv8, Tv10, Tv23, Tv25, Tv28, Tv30 and Tv32 (Fig. 11) while endochitinase activity was high in the isolates Tv3, Tv16, Tv22 followed by Tv23, Tv5, Tv8, Tv30, Tv32, Tv23 and Tv35 (Fig. 12).

(xvi) Development of efficient formulations of *Trichoderma* sp. and entomofungal pathogens with prolonged shelf-life

(a) Addition of pure chitin

Addition of chitin helped in maintaining high CFU (2 x 10^6) in the *T. harzianum* formulation up to 6 months in storage while in the control where no chitin was added, the CFU went down below the recommended level of 2 X 10^6 after 4 months. In chitin amended formulations also by 7^{th} month the CFU was completely reduced. The chitin addition helped in extending the shelf-life by 2 months. In *T. viride* also the chitin addition helped in extending the shelf-life by 2 months only (Fig. 13).

(b) Addition of colloidal chitin

Addition of colloidal chitin 0.2 per cent helped in maintaining the high CFU in the formulations of *T. viride* and extending the shelf-life by 2-3 months compared to control. In *T. harzianum*, the shelf-life was extended by two months (Fig. 14).

(c) Effect of C:N ratio

To study the effect of C:N ratio on the shelf-life, *T. viride* (Tv 23) and *T. harzianum* (Th-10) were grown on the synthetic medium (TSM) with glucose as carbon source and ammonium nitrate or cassamino acids as N source. The C:N ratios, 1:5 and 1:1 did not increase the shelf-life of both *T. viride* and *T. harzianum*. The wider the ratio, higher was the CFU and in shelf-life also, 10:1 and 15:1 ratios helped in having higher CFU up to 6 months only.

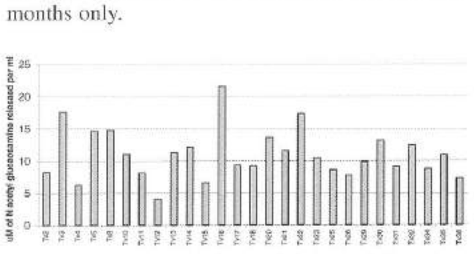

Fig. 11. Exochitinase activity in *Trichoderma viride* isolates

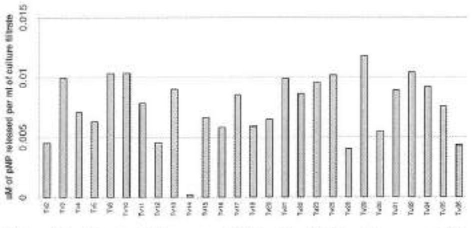

Fig. 12. Endochitinase activity in *Trichoderma viride*

(d) Effect of addition of glycerol

Addition of glycerol at 3 and 6% increased the CFU count in the *T. harzianum* formulations up to 8 months (2.3 to 3 x 10^6 CFU/g). In *T. viride* also, the addition of glycerol helped in retaining high CFU up to 7-8 months when added at 3-6% concentration in production media. In formulations derived from media where glycerol was added at 9 or 12%, the CFU was high up to 6 months compared to the control and 3 or 6 % glycerol added media, but it was reduced after 4 months (Fig. 15).

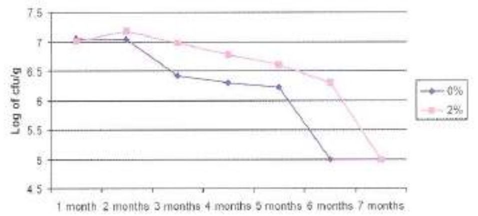

Fig. 13. Effect of addition of pure chitin in talc formulation of *Trichoderma viride* on shelf-life in terms

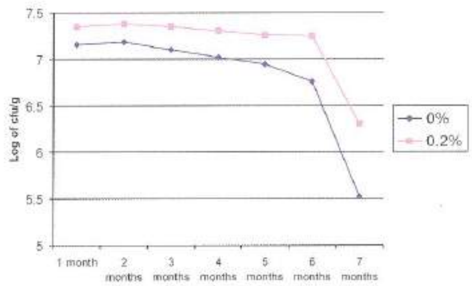

Fig. 14. Effect of addition of colloidal chitin in the production medium of *Trichoderma viride* on shelf-life

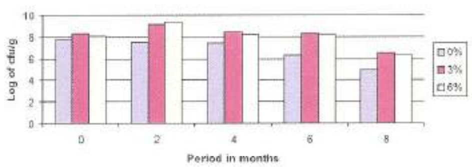

Fig. 15. Effect of addition of glycerol in the production medium on the shelf-life of *Trichoderma harzianum*

(e) Effect of heat shock

To study the effect of heat shock, *T. harzianum* and *T. viride* cultures were grown in fermenter and subjected to the following treatments: heat shock at 40°C for 30 min, 40°C for 60 min, 35°C for 45 min, 35°C for 90 min.

Up to 6 months of shelf-life, formulations from the biomass that has been subjected to the heat shock had higher CFU compared to control. After 6 months, heat shock at 35°C for 90 minutes was found to be the best treatment since even up to 8 months the CFU was not reduced below the recommended level of $2x10^6$.

(f) Effect of moisture content

The effect of different packing methods, i.e. with air in the packet or without air (air being removed using vacuum drier) and different covers (polypropylene and aluminium covers) at different moisture levels was studied. The moisture level started decreasing in the packets with time and after 4 months, the packets packed with air, were having the formulations with less than 2% moisture irrespective of their initial moisture level. Aluminium covers were better than the polypropylene bags in retaining moisture. After two months of storage, it was found that storage without air was better than packing with air in both types of covers.

(g) Effect of addition of chitin on shelf-life of *Beauveria bassiana*, *Metarhizium anisopliae* and *Nomuraea rileyi*

Addition of 0.2% colloidal chitin to the production medium (SDYB) or addition 2% pure chitin to the talc formulation or combination of these treatments extended the shelf-life of *B. bassiana* to 8 months at room temperature (17-32°C). The CFU counts recorded in talc formulations after 8 months of storage at room temperature were $26.8x10^8$CFU/g in the treatment with addition of 0.2% colloidal chitin to the production medium+ addition 2% pure chitin to the talc formulation, 14.4 $x10^8$ CFU/g in the treatment with addition of 0.2% colloidal chitin to the production medium (SDYB), 11.5 $x10^8$ CFU/g in the treatment with addition 2% pure chitin to the talc formulation and $5.6x10^5$ CFU/g in control. Similar results were obtained with stationary cultures also.

In case of *M. anisopliae*, addition of 0.2% colloidal chitin to the production medium (SDYB) or addition 2% pure chitin to the talc formulation helped in extending the shelf-life of *M. anisopliae* to 8 months at room temperature. The un-amended formulations had only 6 months shelf-life at room temperature (Table 12).

Addition of 0.2% colloidal chitin to the production medium (SMYB) or addition 2% pure chitin to the talc formulation from SMYB has reduced the CFU counts of *Nomuraea rileyi* ($29.5x10^8$/g, 24.7 $x10^8$/g respectively) in talc formulations in the initial sample compared to the CFU counts in the talc formulation prepared from unamended medium ($37.8x10^8$/g). Talc formulations of *N. rileyi* prepared from 0.2% colloidal chitin-amended SMYB showed reduced shelf of 3 months compared to the 4 months shelf-life of formulation prepared from un-amended medium. Similarly, addition 0.2% colloidal chitin to the solid substrate production medium (rice) has resulted in reduced spore production of *N. rileyi* ($84.9x10^8$/g) compared to spore production on unamended rice ($89.7x10^8$/g). Shelf-life of *N. rileyi* on rice amended with 0.2% colloidal chitin was reduced to 4 months in comparison with 5 months shelf-life of unamended rice (Table 13).

(h) Effect of addition of polyethylene glycol to the production media on shelf-life of *B. bassiana*, *M. anisopliae* and *N. rileyi*

The CFU counts of *B. bassiana* and *M. anisopliae* recoded in the formulations prepared from the PEG-amended SDYB did not differ significantly from the CFU counts recorded in the formulation prepared from un-amended SDYB in all the samples. The shelf-life of talc formulations of *B. bassiana* and *M. anisopliae* remained at 6 months in PEG-amended as well as unamended media.

Addition of PEG at 1-3% conc. to the SMYB did not influence the CFU counts of *N. rileyi* in talc formulation during storage at room temperature. Shelf-life of *N. rileyi* in talc formulations remained the same (4 months) in PEG-amended and un-amended media.

Table. 12. Effect of addition of colloidal chitin on the shelf-life of talc formulations of *Beauveria bassiana* and *Metarhizium anisopliae*

Treatment	CFU (x10^8) after 8 months in			
	Shaker culture	Stationary culture	Shaker culture	Stationary culture
Addition 0.2% colloidal chitin to SDYB	14.4^b	12.6^b	13.0^a	8.6^b
Addition 2% chitin to talc formulation	12.6^b	8.3^b	8.5^b	5.0^b
Addition 0.2% colloidal chitin to SDYB + Addition 2% chitin to talc formulation	26.8^a	21.6^a	21.5^a	13.2^a
Control (without chitin)	5.6x10^{6c}	1.1^c	1.3^c	1.0^c

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

Table 13. Effect of colloidal chitin on shelf-life of talc and rice grain formulation of *Nomuraea rileyi*

Treatment	CFU/gx10^8 after months of storage				
	0	2	3	4	5
Addition 0.2% colloidal chitin to the production medium, SMYB	29.5^c	10.3^c	1.8^d	0.12^d	0.04^d
Addition 2% chitin to talc formulation prepared from SMYB	24.7^c	8.5^c	1.2^d	0.12^d	0.02^d
Control (Only SMYB)	37.5^b	20.9^b	7.2^c	1.3^c	0.16^c
Addition 2% chitin to the solid production medium, rice	84.9^a	52.4^a	32.9^b	8.9^b	0.8^b
Control (Only rice)	89.7^a	61.6^a	43.7^a	21.3^a	12.4^a

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

(xvii) Isolation, characterization and toxicity of indigenous *Bacillus thuringiensis* strains against lepidopterous pests

Twenty-seven native *Bt* isolates were isolated using a *Bt*-specific medium. Crystal presence was seen in 15 isolates. Three *Bt* isolates were purified from samples of dead larvae belonging to lepidoptera group (*Papilio demoleus, P. polytes* and *Eariadne merione*) from the Bannerghatta Biological Park. Twenty-one forest soil samples were collected from Chattisgarh and seven *Bt* isolates were purified on *Bt* -specific medium.

The fifteen indigenous *Bt* isolates were tested for toxicity against *Plutella xylostella* and *H. armigera*. The isolates *Bt*4 and *Bt*15 exhibited 66.7 and 50.0% mortality at 10^{-2} dilution. The LC_{50} values were calculated for four of the *Bt* isolates against *P. xylostella* and compared with the standard HD-1 strain. It was observed that the highest toxicity was shown by the isolate Bt4 (log 5.83 spores/ml) and the lowest was exhibited by Bt8 (log 7.97 spores/ml) (Fig. 16 and 17).

The isolates *Bt*4 and *Bt*15 were toxic at 10^{-2} dilution by inflicting 66.7 and 50 per cent mortality respectively of *H. armigera*. It was observed that the highest toxicity was shown by the isolate *Bt*4 (log 7.25 spores/ml). However none of the indigenous isolates was comparable with the standard HD-1 strain. *Bt* isolates which were isolated from the dead larvae of *P. demoleus, P. polytes* and *E. merione* were designated as Btbg1, *Bt*bg2 and Btbg3 and the isolates Btbg2 gave 66% mortality of *H. armigera* after 72 h.

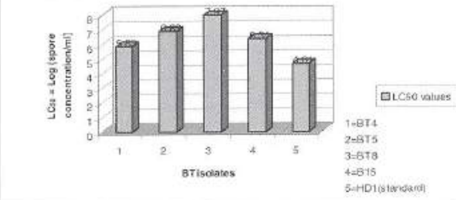

Fig. 16. Toxicity of native *Bt* isolates to *Plutella xylostella*

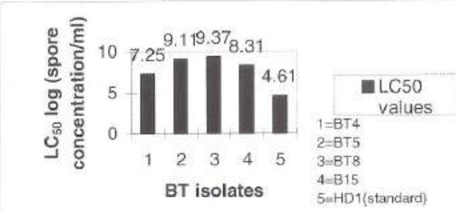

Fig. 17. Toxicity of native *Bt* isolates to *Helicoverpa armigera*

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

Studies were conducted to isolate and evaluate endophytic bacteria and rhizospheric bacteria for their growth promoting and biological control ability. A total of five endophytic bacteria were isolated from healthy chickpea plants. The endophytic bacteria were identified at IMTECH, Chandigarh as *Bacillus megaterium* (MTCC6533), *Bacillus* sp. (MTCC6535), *Bacillus circulans* (UAS6534), *Erwinia herbicola* (UAS6720) and *Enterobacter agglomerans* (MTCC6536). This is the first report of identification of endophytic bacteria from chickpea.

Two rhizospheric isolates obtained from healthy tomato plants in a field heavily infested with wilt in Kolar district of Karnataka showed antagonism against *Fusarium oxysporum* f.sp. *lycopersici*. The isolates were purified and identified at IMTECH, as *Pseudomonas aeruginosa* (MTCC7512) and *Cryptococcus albidus* (MTCC7436).

The highest root length of 23.7 cm was observed in *B. megaterium* and the highest shoot length of 17.8 cm was observed in the *E. agglomerans*-treated chickpea plants. All the endophytes showed positive activity for plant growth promotion. The highest vigour index of 4116.67 was noticed in plants treated with *B. megaterium*.

An experiment was conducted to test the endophytes against *Rhizoctonia solani* under greenhouse. Highest germination of 75.2% was observed in fungicide-treated plants but the *Bacillus* sp.-treated plants were also comparable with fungicide-treated, which exhibited 66% germination. The lowest germination of 40.8% was recorded in pathogen control. Highest root length was recorded in fungicide-treated (6.7 cm) after 8 days of germination but *B. megaterium* and *E. herbicola* also gave good response and recorded a root length of 6.5 and 6.2 cm, respectively. Highest shoot length of 5.9 cm was again recorded with fungicide-treated but shoot length varied from 4.3 to 4.7 cm was recorded with *B. megaterium, B. circulans, E. herbicola* and *P. fluorescens* treatments. Highest shoot length of 5.9 cm was again recorded with fungicide treatment but shoot lengths varying between 4.3 to 4.7 cm was recorded with *B. megaterium, B. circulans, E. herbicola* and *P. fluorescens* treatments.

Seed bacterization with endophytic bacteria resulted in significantly higher phenol content when compared with control in 7 day-old plants. The phenol content peaked at 4 days and highest was recorded with *B. megaterium* (505 µg/g) and the lowest was in control (290 µg/g) (Fig. 18). Phosphate solubilization was seen only in *B. megaterium* on Sperber's medium. The maximum solubilization zone was observed with *B. megaterium* (35.3 mm) at 120 h of incubation (Table 14).

Table 14. Phosphate solubilization by bacterial isolates on Sperber's medium

Bacteria	Solubilization zone (mm)				
	Incubation period (h)				
	24	48	72	96	120
Bacillus megaterium	20.0	24.7	28.3	31.0	35.3
Bacillus subtilis	17.0	25.3	27.3	30.7	34.7
P. fluorescens	15.3	20.0	27.3	30.3	34.3
CD (*P*=0.05)	4.22	NS	NS	NS	NS

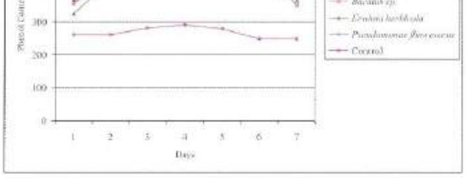

Fig. 18. Changes in phenol content ((µg/g)) in chickpea plants after seed treatment with rhizospheric and endophytic bacteria

(xix) Investigations on Entomopathogenic nematodes

(a) Mass production of EPN

Supplementation of Wout's medium with casein peptone increased the yield of infective juveniles of *Steinernema carpocapsae* significantly. In Wout's medium the yield was 62×10^5 IJ/4 g of medium while supplementation with casein peptone increased the yield to 89×10^5 IJ/4 g.

(b) Effect of antidesiccants in storage - *Steinernema carpocapsae* (PDBC-EN-11) & *Heterorhabditis bacteriophora*

Nematodes survived well in glycerine and castor oil up to 45 days and pathogenicity was not adversely affected. They remained under quiescence in both the antidesiccants. Survival in liquid paraffin was not affected adversely up to 15 days at 0.25 & 0.5%. Adverse effect on survival was observed when stored for 45 days at all concentrations with significantly lower survival rate. Survival rate in Triton X100 and Tween 20 was on par with liquid paraffin for 15 days of storage of *Heterorhabditis bacteriophora*. The same trend was observed for *S. carpocapsae* with 93% in 0.5% Tween for 15 days. Pathogenicity of *S. carpocapsae* and *H. bacteriophora* stored in castor oil was not altered. *Heterorhabditis bacteriophora* was more sensitive to antidesiccants.

(c) Effect of UV protectants on storage

The effect of para-ammino-benzoic acid (PABA), robin blue, ujala and sodium sulfate on survival and pathogenicity of *S. carpocapsae* and *H. bacteriophora* was monitored. Highest survival of *S. carpocapsae* was in PABA followed by sodium sulfate. Maximum survival rate observed was 95, 94 & 83% and 93, 83 & 76% during 15,30 & 45 days after storage in the least concentration of PABA and sodium sulphate, respectively. Pathogenicity was not altered with sodium sulfate and PABA. Storage in all the agents at lower concentration enhanced the survival and pathogenicity compared with control.

(d) Persistence of EPN on cotton leaf treated with antidesiccants

Treatments with castor oil protected nematodes at 0.25 0.5, 1% for 20 min of exposure. The maximum survival of *S. carpocapsae* (36%) was found at 10 minutes exposure period with 1%. Exposure for 30 minutes proved lethal for nematode survival. The susceptibility of *S. carpocapsae* to desiccation was evident in control where survival rate was 7, 3 & 0% at 10, 20 & 30 minutes of exposure. In case of *H. bacteriophora*, lower concentration proved effective in increasing survival (Fig. 19).

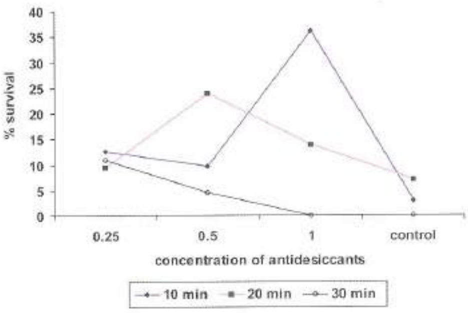

Fig. 19. Survival of *Steinernema carpocapsae* PDBC EN 11 on cotton leaf treated with castor oil exposed to 275 W/m^2 at 35°C

(e) Persistence of EPN on cotton leaf treated with UV protectants

Sodium sulfate at concentrations of 0.25, 0.5 and 1.0% as UV protectant offered protection to *S. carpocapsae* and *H. bacteriophora* under different exposure periods. Maximum survival of *S. carpocapsae* (52%) was in 1% and that of *H. bacteriophora* (44%) in 0.25 % concentration for 10 minutes exposure. A positive correlation was observed with survival rate and concentration in case of *S. carpocapsae* while a negative response was evident in *H. bacteriophora*. As the exposure time progressed from 10 to 30min. number of IJs remained viable reduced from 45 to 25%, 45 to 28% and 52 to 29% in 0.25%, 0.5 and 1% concentration, respectively, for *S. carpocapsae*. Maximum survival rate was observed in lower concentrations in case of *H. bacteriophora* that significantly declined when exposure period progressed from 10 to 30 minutes. In general *S. carpocapsae* survived better compared to *H. bacteriophora* (Fig. 20).

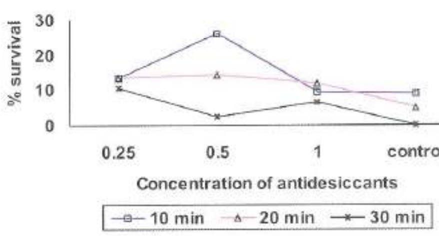

Fig 20. Survival of *Heterorhabditis bacteriophora* on cotton leaf treated with castor oil exposed to sun at 275 W/m^2

(f) Formulation

Steinernema carpocapsae and *H. bacteriophora* were formulated in Kaolin powder at 12 and 15% moisture levels and dosages of 20,000 and 40,000 IJs / g and stored at room temperature. Viability of formulated IJs as well as pathogenicity against *G. mellonella* larvae were studied. Irrespective of moisture level and dosages *H. bacteriophora* gave higher mortality of *G. mellonella* than *S. carpocapsae*.

(g) Storage and bulk transport

Carboxymethyl cellulose 3%, gum tragacanth and tragacanth and acacia-based gel formulations were found promising with 100% survival of *S. carpocapsae* IJs for 30 days under storage. Absolute survival was observed in CMC 1 & 2% after 15 days and survival was reduced to 88& 92% after 30 days storage. In carbopol based formulation, 100% survival was observed only during first week which reduced to 95, 88 & 80% after 14, 21 & 30 days, respectively. Gum based gel formulation is suitable alternative for storage of *S. carpocapsae* at 30°C for 30 days and found suitable for transport.

Nematodes were extracted from gel formulation and sponge and evaluated for pathogenicity against *H. armigera* in laboratory. Maximum mortality of 96.6 and 100% of *H. armigera* larvae was observed due to nematodes from gel and sponge after 40 h of exposure. It is concluded that storage of *S. carpocapsae* in gel and sponge is safe and without any adverse effect.

(h) Field efficacy of *Heterorhabditis indica* and *S. carpocapsae* against white grubs in Tobacco

Heterorhabditis indica talc-based formulation @ 5 b/ha applied in field gave significant control of *Holotrichia* in tobacco in Shimoga, Karnataka. Establishment of transplants, and cured leaf yield were significantly increased (Table 15) and was comparable with other treatments.

Table 15. Evaluation of plant origin insecticides and bioagents against root grubs in FCV tobacco in field

Treatment	Seedling establishment (%)	Cured leaf yield (kg/ha)	Nicotine (%)
Neem cake 40g/pl	86.7[a]	1212[a]	2.52[a]
Neem cake 60g/pl	88.3[a]	1197[a]	2.51[a]
Pongamia cake 40g/pl	86.7[a]	1199[a]	2.24[b]
Pongamia cake 60 g/pl	85.8[a]	1162[a]	2.45[a]
Metarhizium 10^8 /ml	87.1[a]	1197[a]	2.12[b]
Heterorhabditis 5 b/ha	87.9[a]	1210[a]	2.11[b]
Control	69.6[b]	1089[b]	2.12[b]

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

(xx) Biological suppression of plant parasitic nematodes

(a) Diversity of fungi antagonistic to plant parasitic nematodes

Studies on diversity of native antagonistic fungi of Karnataka (4 isolates of *Paecilomyces lilacinus* and six of *Pochonia chlamydosporia*) showed that all the isolates were effective against root-knot, reniform and cyst nematodes. Based on temperature and pH optima, growth factors, yield per gram substrate and per cent parasitisation of egg masses, PDBC PL55 and PDBC PL58 of *P. lilacinus*, and PDBC PC56, PDBC PC69 and PDBC PC72 of *P. chlamydosporia* were observed to be the better than other isolates (Table 16).

Isolates of *P. chlamydosporia* were characterized through PCR using beta-tubulin gene marker and Genbank numbers were obtained.

(b) Molecular identification of antagonistic fungi (*Pochonia chlamydosporia*)

A native isolate of *P. chlamydosporia* (PDBC PC56) was extracted by CTAB-chloroform-isopropanol method, precipitated in ethanol and stored in Tris-EDTA buffer. This was deposited at NCBI Genbank, Maryland, USA with an accession number as DQ417603 apart from the three isolates of the same depositd earlier by PDBC.

Table 16. Effect of pH and temperature on spore production and parasitisation					
Fungus	Optimal range		Spore yield /g rice grain*	Per cent parasitised	
PDBC isolate	Temp.	pH		Eggs	Egg masses
P.lilacinus PDBC PL55	22-37	5.5-8.0	10.8	84	68
P. lilacinus PDBC PL56	20-37	5.6-8.0	9.3	76	40
P. lilacinus PDBC PL57	24-39	5.4-7.8	9.7	78	46
P. lilacinus PDBC PL58	23-37	5.5-8.0	10.7	86	66
P. chlamydosporia	20-37	5.6-8.2	9.7	78	69
*P. chlamydosporia*PDBC PC56	20-37	5.6-8.2	9.7	76	66
*P. chlamydosporia*PDBC PC69	21-36	5.6-8.4	9.2	77	69
*P. chlamydosporia*PDBC PC72	20-37	5.8-8.0	9.9	74	64
*P. chlamydosporia*PDBC PC118	22-39	5.9-7.9	7.9	60	50

* $\log_{10}$ values

(c) Low-cost and rapid mass production of nematode antagonists

Among the solid media, broken barley, maize bran, broken corn and wheat bran recorded 14-16 days of production cycle and a spore yield (log10 values) of 7.5059-6.7782 followed by other solid media. The caking and clumping was minimum at harvest in broken barley, broken corn, wheat bran and maize bran at 1:1 proportion with water (w/v). In liquid media production system, the mycelial biomass weight was higher in two modified media and addition of 0.5% yeast extract increased the biomass in respective liquid media. The solid, liquid and di-phasic media examined were from natural sources, which can be supplemented with synthetic nutritional factors for enhancing the production cycles and yields in a given set of conditions.

(d) Influence of soil types on the behavior of *Paecilomyces lilacinus* and pathogenicity against root-knot nematodes under pot conditions

Behaviour of *P. lilacinus* isolate PDBC PL55 was examined in six typical soils with different physical properties. *P. lilacinus* recorded a decline in CFU/g soil in 2-3 week of incorporation, which recorded higher CFU in subsequent weeks of observation till 6-8 weeks in all the 4 soils. After 6-8 weeks of treatment, the fungus exhibited a decline in spore CFU, which stabilized at 10-12 weeks. Typically, *P. lilacinus* recorded higher CFU, root colonization and egg mass parasitisation in soils with comparatively higher organic carbon at all the pH categories.

(e) Evaluation of talc formulations of *P. lilacinus* and *P. chlamydosporia* against root-knot nematodes in gherkins

Incorporation of *P. lilacinus* or *P. chlamydosporia* talc formulations at 30 kg/ha along with 200 kg/ha of vermicompost in furrows before sowing gherkin seeds recorded 54-72% infection of egg masses, reduction in the nematode populations by 22-38% in soil and 38-66% reduction in root-knot nematode infection in roots, in 75 days of crop growth.

(f) Studies on integration of soil solarization using plastic mulching with neem cake and *P. chlamydosporia*

Soil solarization using plastic mulches for 21 days during the month of May-June followed by the incorporation of *P. chlamydosporia* (2×10^{10} spores/ m^2) + neem cake (1kg/m^2) before sowing of tomato seeds in the nursery recorded higher fungal CFU/ g in soil after two months and better root colonization compared to the incorporation of the fungus and neem cake without solarization using plastic mulch. Mulching with clear LDPE 25 µm film for 3 weeks recorded a maximum soil temperature of 63°C while it was 46-48°C without mulching. Solarization followed by incorporation of neem cake and *P. lilacinus* recorded higher parasitisation of egg masses in tomato, while native fungal flora declined significantly compared to untreated soil. *P. lilacinus* introduced recorded better establishment.

(xxi) Development of database on microbial biocontrol agents in India

HTML pages were developed for entomofungal pathogens as well as bacterial and fungal antagonistic organisms to access the abstracts into various topics like history, taxonomy, biology, host range/target pests and diseases, epizootics, laboratory bioassay/glasshouse studies, culturing and storage, mass production and formulations/application and dosage, compatibility with insecticides & botanicals, compatibility with other biocontrol agents and field trials.

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

The post-harvest pathogens isolated from mango fruits were *Colletotrichum gloeosporioides*, *Aspergillus* spp., *Pecillium* spp. and *Diplodia* spp. Bacterial cultures were isolated from mango surface were tested for their efficacy against *C. gloesporioides*, the anthracnose pathogen. In storage experiments isolates 2 and 4 gave significant reduction in post-harvest fruit rot damage.

ALL INDIA CO-ORDINATED RESEARCH PROJECT ON BIOLOGICAL CONTROL

3.3 Biological control of plant diseases using antagonistic organisms

(i) Bioefficacy of oil-based and talc-based formulations of biocontrol agents against foliar diseases of rice

(a) GBPUA&T

Although there was relatively higher yield in organically cultivated Kalanamak when sprayed with oil based formulation than talc-based formulation of either *T. harzianum* or *P. fluorescens*. These differences were not significant both for brown spot intensity as well as yield. In general *P. fluorescens* was more effective than *T. harzianum* (Table18).

(b) PAU, Ludhiana

Talc as well as oil-based formulation of *T. harzianum* and *P. fluorescens* were evaluated against brown spot of rice on *Basmati* variety 386 at Usman village, Distt. Amritsar during 2005. Foliar sprays of antagonist @ 10g/litre were initiated just after the appearance of disease. The antagonists were compared with chemical fungicide Indofil Z-78 @ 500 g/acre and untreated control.

It was observed that the severity of disease varied from 6.0 to 7.7% in different treatments in *Basmati* rice before spraying. After three sprays the terminal severity was found to be lowest in Psf (Talc) i.e 8.5% followed by chemical control (Indofil Z-78) where severity was 9.3%. It was further found that talc-based formulation of Psf showed better efficacy (8.5%) than oil (13.3%). All the treatments were significantly superior in increasing grain yield as compared to control. Highest yield (29.2 q/ha) was obtained in talc-based Psf and was at par with chemical fungicide Indofil Z-78 (28.5 q/ha) (Table18).

(c) AAU, Jorhat

The intensity of brown spot disease of rice was very low during the cropping season. However, the bio efficacy of oil and talc-based formulation of *T. harzianum* and *P. fluorescens* in different combination showed that the lowest occurrence of brown spot was observed in the plot treated with *T. harzianum* (10 g/l talc based + 20 g/l FYM), but maximum yield (3171.7 kg/ha) was recorded in the plot treated with foliar spray of talc-based *T. harzianum* (10 g/l) followed by oil-based *T. harzianum* (10 g/l) and talc-based *Pseudomonas fluorescens* (20 g/l). However, there was no significant difference among the treatments including control (Table17).

(d) Pea (GBPUA&T. Pantnagar)

In an experiment on pea (var. Arkle), *T. harzianum* and *P. fluorescens* formulations were used and all the treatments significantly reduced the rust severity and increased yield over control. There was no significant difference between talc and oil-based formulations. In general spray of *P. fluorescens* was more effective than *T. harzianum* (Table 18).

Table 17. Efficacy of antagonists for the control of brown spot of rice

Treatment	GBPUA&T		AAU (Jorhat)		PAU	
	Disease intensity (%)	Yield (q/ha)	Disease intensity (%)	Yield (q/ha)	Disease intensity (%)	Yield (q/ha)
Foliar spray with *Trichoderma harzianum* (10 g/l) talc-based	38.8[b]	37.7[b]	2.8[b]	31.7	14.5[b]	23.3[b]
T. harzianum equivalent dose oil-based	40.3[b]	38.2[b]	2.5[ab]	30.9	17.6[c]	22.5[b]
Pseudomonas fluorescens (10 g/l) talc-based	25.6[a]	44.6[a]	2.5[ab]	31.1	8.5[a]	29.2[a]
P. fluorescens equivalent dose oil-based	24.1[a]	45.8[a]	2.2[ab]	31.1	13.3[b]	23.3[b]
T. harzianum (10 g/l) talc-based+20 g/l FYM	30.4[a]	40.3[a]	2.0[a]	31.2	-	-
P. fluorescens (10 g/l) talc-based+20 g/l FYM	21.8[a]	45.4[a]	2.1[a]	31.4	-	-
Foliar spray with 20 g/l FYM powder	68.5[c]	25.4[c]	4.3[c]	28.8	-	-
Indofil M-45	-	-	-	-	9.3[a]	28.5[a]
Control	76.5[c]	26.5[c]	4.7[c]	27.7	20.1[c]	17.7[c]

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

Table 18. Efficacy of antagonists for the control of rust disease in peas

Treatment	Rust intensity (%)	Yield (kg/ha)
Foliar spray with *Trichoderma harzianum* (10 g/l) talc-based	27.5[bc]	412[b]
T. harzianum equivalent dose oil-based	24.3[b]	388[b]
Pseudomonas fluorescens (10 g/l) talc-based	16.0[a]	426[ab]
P. fluorescens equivalent dose oil-based	18.4[a]	458[a]
T. harzianum (10 g/l) talc-based + 20 g/l FYM	30.0[bc]	403[b]
P. fluorescens (10 g/l) talc-based + 20 g/l FYM	14.2[a]	458[a]
Foliar spray with 20 g/l FYM powder	32.0[c]	326[c]
Control	38.0[d]	305[c]

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

(ii) *In vitro* compatibility between entomopathogens and fungal and bacterial antagonists

(a) GBPUA &T

Both *T. harzianum* (TH) and *P. fluorescens* (PsF) inhibited the growth of *B. bassiana*. Per cent inhibition being 41.7 and 71.3 for TH and PsF, respectively. After 15 days of inoculation TH totally overgrew colony of *B. bassiana*. Compatibility *B. bassiana* and two more entomopathogenic fungi *M. anisoplae* and *V. lecanii* with *T. harzianum* PBAT-43 (TH) was tested by Bangle method. As shown in Table 19, TH significantly reduced the growth of both these entomopathognic fungi. Maximum inhibition was of *V. lecanii*. Both *B. bassiana* and *M. anisoplae* were equally sensitive.

The fungal bio-control agent *T. harzianum* was not compatible with any of the bio-insecticides tested *viz*. *B. bassiana*, *M. anisopiae* and *V. lecanii* evaluated in the present study. Per cent inhibition by *T. harzianum* on *B. bassiana*, *M. anisopliae* and *V. lecanii* after 8 and 12 days were 31.7, 44.5% and 35.1 and 44.2%, 42.2 and 61.5%, respectively (Table 20). Zone of overlapping recorded was 6.00 mm with *B. bassiana*. *T. harzianum* did not overgrow *M. anisoplae* and *V. lecanii* up to 12 days of inoculation. It showed zone of inhibition with these two entomopathogenic fungi i.e. *M. anisopliae* (5.00 mm) and *V. lecanii* (2.00 mm). Although under *in vitro* condition all entomopathogenic fungi including *B. bassiana*, were

Table 19. Effect of *Trichoderma harzianum* or *Pseudomonas fluorescens* on mycelial growth of *Beauveria bassiana* in dual culture method

Treatment	Average per cent inhibition after (days)	
	10	15
T. harzianum	41.7	100.0
P. fluorescens	71.3	77.6

antagonized by *T. harzianum*, their interaction should be evaluated under *in vivo* condition particularly in soil and cow-dung based compost like FYM.

Table 20. Inhibition of mycelial growth of *Beauveria bassiana*, *Metarhizium anisoplae* and *Verticillium lecanii* by *Trichoderma harzianum* in bangle method		
Treatment	Average per cent inhibition after (days)	
	8	12
B. bassiana	31.7	44.5
M. anisopliae	35.1	44.2
V. lecanii	42.2	61.5

(b) PDBC

The fungal antagonists (*T. harzianum*, *T. viride* and *T. virens*) inhibited the growth of the three entomopathogenic fungi tested viz., *B. bassiana* (55.2, 55.8 & 55.2% inhibition respectively), *M. anisopliae* (64.6, 54.4 & 64.6% inhibition respectively) and *V. lecanii* (56.3, 45.4 & 45.4% inhibition, respectively). *Trichoderma harzianum* caused lysis of hyphae and spores of *B. bassiana*, *M. anisopliae* and *V. lecanii*.

(iii) *In vitro* compatibility between *B. bassiana*, *M. anisopliae* and *V. lecanii*.

The compatibility between *B. bassiana* and *M. anisopliae*, *B. bassiana* and *V. lecanii* and *M. anisopliae* and *V. lecanii* was studied using dual culture test. The results showed mutual inhibitions among these fungi (Table 21).

(iv) 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)

Although both low and high ISR inducing strains of *Trichoderma* and *Pseudomonas* significantly reduced zonate leaf spot severity and improved plant growth in comparison with control when applied through seed and/or compost, high ISR inducing strain (PBAT-39) of *T. harzianum* provided best protection under field condition (Tables 22, 23 and 24). Growth promoting effect of PsF was better than TH, when it was applied through seed and/or compost. Mixed formulation of TH + PsF was most effective for foliar application.

Table 21. *In vitro* compatibility between *Beauveria bassiana*, *Metarhizium anisopliae* and *Verticillium lecanii*		
Dual culture	Visual and Microscopic observation	Inhibition (%)
B. bassiana vs *M. anisopliae*	1. Mutual inhibition of *B. bassiana* and *V. lecanii* 2. Inhibitory zone observed at contact point 3. No hyphal/ spore abnormalities seen in *B. bassiana* and *M. anisopliae*	35.9 (*B. bassiana*) 23.9 (*M. anisopliae*)
B. bassiana vs *V. lecanii*	1. Mutual inhibition of *B. bassiana* and *V. lecanii* 2. Inhibitory zone observed at contact point 3. No hyphal/ spore abnormalities seen in *B. bassiana* and *M. anisopliae*	31.4 (*B. bassiana*) 28.2 (*V. lecanii*)
M. anisopliae vs *V. lecanii*	1. Mutual inhibition of *M. anisopliae* and *V. lecanii* 2. No hyphal/ spore abnormalities seen in *B. bassiana* and *M. anisopliae*	32.2 (*M. anisopliae*) 34.4 (*V. lecanii*)

Table 22. Effect of seed biopriming with biocontrol agents on severity of zonate leaf spot and growth of sorghum			
Biocontrol agents	Disease severity (%)	Height (cm)	Collar diameter (cm)
TH PBAT-43	38.2^{b}	170.5^{a}	1.2^{a}
TH PBAT-39	26.5^{a}	170.3^{a}	1.2^{a}
PsF PBAP-27	35.7^{b}	177.5^{a}	1.2^{a}
Control	57.9^{c}	132.0^{b}	0.8^{b}
Means followed by similar letters are not different significantly by LSD (P=0.05)			

Table 23. Effect of seed biopriming and compost colonization with different biocontrol agents on zonate leaf spot and growth of sorghum			
Treatment	Disease severity (%)	Height (cm)	Collar diameter (cm)
TH PBAT-43	37.1[b]	180.5[ab]	1.23[a]
TH PBAT-39	21.8[a]	176.4[a]	1.29[a]
PsF PBAP-27	34.7[b]	187.5[b]	1.25[a]
Control	65.7[c]	139.0[c]	1.01[b]
Means followed by similar letters are not significantly different (*P*=0.05)			

Table 24. Effect of foliar spray of biocontrol agents on severity of zonate leaf spot	
Treatment	Disease severity (%)
TH PBAT-43	41.9[a]
TH PBAT-39	44.2[a]
PsF PBAP-27	39.2[a]
TH PBAT-43 + PsF PBAP-27	36.1[a]
Contaf	41.8[a]
Control	55.2[b]
Means followed by similar letters are not significantly different (*P*=0.05)	

(v) Large scale field-testing of *Trichoderma* at farmers' field (GBPUA & T)

Seed treatment with *T. harzianum* followed by one to two sprays of mixed formulation of *T. harzianum* + *P. fluorescens* enhanced the yield of chickpea as well as vegetable pea when used in large area (Table 25).

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

Experiments were conducted on the efficacy of nematode antagonists *T. harzianum* and *Pochonia chlamydosporia* against the cyst nematodes of pigeonpea at Anand and Coimbatore.

(a) AAU (A)

All the bioagents gave >50% suppression of cyst nematode, whereas, carbofuran showed maximum reduction 73.13% (Table 26). Cysts recovered from fungus-treated plots did not showed infection or parasitism.

Table 25. Large-scale field-testing of *Trichoderma* application in farmers field				
Chickpea cv. HR-1, Farmer: Sukhdev Singh, Address: Tanda, Udham Singh Nagar, Uttaranchal				
Treatment	Plant height (cm) (30 days)	Plant stand (75 days)	Area (acres)	Yield (q/acre)
Trichoderma	8.9	43	350.0	9.0
Control	8.1	37	0.5	7.0
Pea: Arkle, Farmer: Sukhdev Singh, Address:Tanda, Udham Singh Nagar, Uttaranchal				
Trichoderma	15.7	51.0	250.0	5.0
Control	14.6	43.5	0.5	4.1
Pea: Arklem, Farmers: Mr. Virendra Singh, Benazir Farm, Rampur, UP, Mr. Bhupendra Singh, Swarg Farm, Bilaspur, Rampur, UP				
Trichoderma	16.4	54.0	125.0	40.0
Control	13.2	45.5	1.0	28.0

Table 26. Efficacy of antagonists on cyst nematodes in pigeonpea (var. Tue 100)			
Treatment	Plant height (cm)	Final cyst* population/250 cc soil	Seed yield (kg/ha)
Trichoderma harzianum	7.63[b]	62 (53.73)	386.0[b]
Pochonia chlamydosporia	7.59[b]	55 (58.95)	368.0[b]
T. harzianum + *P. chlamydosporia*	7.47[b]	54 (59.70)	355.0[b]
Carbofuran	7.7[b]	36 (73.13)	488.0[a]
Control	3.7[a]	134	205.0[c]
Treatments means with the letter(s) in common are not significant by DMRT at (*P*=0.05); Figures in parentheses represent per cent reduction			

(b) TNAU

Application of *T. harzianum* 5 kg/ha plus *P. chlamydosporia* 20 kg/ha reduced the number of eggs/cyst, final cyst population, and seedling mortality (9.4%), and increased seed germination, plant growth and yield (550 g/plant) (Table 27).

3.4. BIOLOGICAL SUPPRESSION OF SUGARCANE PESTS

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

The experiment was laid out in a 0.2 ha field of ratoon crop (var. Co 7717), with IPM module (selecting healthy seed, dipping of seed setts in 0.075% malathion, detrashing of dried leaves and release of coccinellids *Chilocorus nigrita* and *Pharoscymnus horni* @ 2000 adults/ha three times from September to October) compared with farmers' practice (treatment of sugarcane setts with gamma HCH @ 1.25 kg a.i./ha at sowing for termite and shoot borer control and soil application of carbofuran @ 1.0 kg a.i./ha for control of top borer during the first week of July) and an untreated check. The incidence of scale rose from 7.3 per cent (at the time of ratooning) to a maximum of 45.3 per cent in untreated check during end September after one month of stripping of lower leaves and just before the first release of the predators *C. nigrita* and *P. horni*. In IPM module and the farmers practice plots, the incidence at this interval was 33.3 and 43.4 per cent, respectively (Table 28). After the second liberation of the predators, the IPM plot recorded the lowest incidence and intensity of the scale. At harvest, the IPM plot recorded 28.7 and 19.8 per cent less scale incidence and intensity than the untreated check. However, the infestation of scaleS in farmer's practice plot was not significantly different from untreated check at the time of harvest.

ii. Biological control of *Pyrilla perpusilla*

(a) IISR

The spatial and temporal variations in the population size of various stages of pyrilla and their parasitoids were recorded at IISR, Research farm on sugarcane variety CoLk8102. The number of eggs of pyrilla was maximum on lower leaf (0.843) in comparison to upper (0.024) and middle leaves (0.371) and egg parasitisation was also maximum on lower leaves (17.62). It appeared that the high level of host population favoured the searching efficiency as well as multiplication rate of egg parasitoids resulting in high level of egg parasitism by *Cheiloneurus pyrillae* and *Oenocyrtus pyrillae*.

The pyrilla population was higher on upper leaves in comparison to middle and lower leaves. However adult parasitisation was at par on lower, middle and upper leaves. The maximum number of cocoons of *Epiricania melanoleuca* was observed on middle leaves. The eggs and cocoons of *Epiricania* were collected from areas of

Table 27. Biological control of cyst nematodes on pigeonpea (var. Coorg 7)

Treatment	Final cyst population	Seedling mortality	Plant height (cm) 30 DAS	Grain yield per plant(g)
T. harzianum 5 kg/ha talc formulation (10^8 spores/g)	61.3 (-21.5)	13.4	17.4	520.0
P. chlamydosporia 20 kg/ha talc formulation (10^8 spores/g)	58.6 (-25.7	14.1	16.9	535.0
T. harzianum 5 kg/ha + *P. chlamydosporia* 20 kg/ha	51.0 – (36.7)	9.4	22.4	550.0
Carbofuran (2kg a.i/ha)	45.8 (- 50.2)	2.3	27.3	640.0
Control	145.9 (+ 41.0)	19.2	15.2	370.0

Table 28. Evaluation of BIPM module for the management of scales in sugarcane

Treatment	Per cent scale infestation during					
	March	September	November		February	
			Incidence	Intensity	Incidence	Intensity
IPM module	6.3	33.3	47.1	13.3	48.0	13.4
Farmers' practice	8.6	43.4	67.1	15.9	66.7	17.2
Untreated check	7.3	45.3	64.7	16.4	66.9	16.9

predominance and distributed to the farmers of villages around Pravaranagar and Ahmednagar (Maharashtra).

(b) CCSHAU

During 2005 sporadic incidence of pyrilla was observed in Haryana from August to October. *Epiricania melanoleuca* and egg parasitoids of *Pyrilla 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 73750 egg-masses and 53620 cocoons of *E. melanoleuca* and 98,375 parasitised egg masses of *P. perpusilla* were supplied to farmers for liberation in 4750 ha of sugarcane, sorghum and rice fields.

iii) Evaluation of *T. chilonis* against plassey borer (AAU, Jorhat)

Field evaluation of *Trichogramma chilonis* against the plassey borer, *Chilo tumidicostalis* was conducted at Sugarcane Research Station, Buralikson. Nine releases of *T. chilonis* @ 50,000/ha at 10 days interval were compared with Farmer's practice with two treatments on var. Dhansiri (CoBLN 9605). Release of *T chilonis* resulted in lower pest incidence compared to farmers' plot and the per cent parasitism was 34 and 12, respectively. Higher yield was obtained in parasitoid released plots compared to farmers' practice (Table 29).

iv) Evaluation of *T. chilonis* (temperature-tolerant strain) against the early shoot borer (PAU)

Field evaluation of temperature-tolerant strain (TTS) of *T. chilonis* developed by PDBC was carried out at village Mehli (Distt. Nawanshahar) and village Khera (Distt Kapurthala).

At Mehli, the pest incidence in control plots was 13.6 per cent, which was higher than in plots receiving temperature-tolerant strain of *T. chilonis* (6.4%) and Ludhiana strain of *T. chilonis* (6.6%). The parasitisation in temperature-tolerant strain (31%) was slightly higher than Ludhiana strain (27.7%). No parasitisation was observed in control and chemical control plots. The yield in temperature-tolerant strain released plot was 771.8 q/ha compared to 762.3 q/ha in chemical control plot. The Ludhiana strain recorded 759.5 q/ha, which was on par with chemical control. The cost: benefit ratio was highest in temperature-tolerant strain (1:8.6) followed by *T. chilonis* local strain (1:6.99) and chemical control (1:3.98). A similar trend was observed at Village Khera, where the reduction in damage over control was 50.7% in temperature-tolerant strain and 52.2% in chemical control. The parasitism was very high (28.7%) in released fields and nil in control and chemical control plots. The cost: benefit ratio in temperature-tolerant strain (1:6.25) was higher than in chemical control (1:3.63) (Table 30).

Table 29. Evaluation of *Trichogramma chilonis* against plassey borer (var. CoBLN 9605)

Treatment	Healthy canes (%)	Infected canes (%)	Egg parasitism (%)	Reduction in damage over control (%)	Yield (t/ha)
Nine releases of *T. chilonis* (0.50 lakhs/ha) at 10 days intervel	80	20	34	44	78
Farmers' practice	55	45	12	-	54

Table 30. Evaluation of *Trichogramma chilonis* (temperature-tolerant strain) against *Chilo infuscatellus* (sugarcane var. Coj 83)

Treatment	Mehli village			Khera village		
	Incidence of shoot borer (%)	Yield (q/ha)	Cost benefit ratio	Incidence of shoot borer (%)	Yield (q/ha)	Cost benefit ratio
T. chilonis (temperature-tolerant strain)	6.4[a]	772[a]	1:8.6	6.8[a]	680[a]	1:6.3
T. chilonis (local strain)	6.6[a]	796[b]	1:7.0	-	-	-
Padan (@ 25 kg/ha)	6.2[a]	762[ab]	1:3.4	6.6[a]	683[a]	1:3.6
Control	13.6[b]	706[c]	-	13.8[b]	632[b]	-

Means followed by similar letters are not significantly different (P=0.05) by DMRT; Releases were made @ 0.50 lakhs at 10 days interval

v) Field evaluation of *Trichogramma japonicum* and *Tetrastichus howardi* against the top borer, *Scirpophaga excerptalis*

(a) SBI

Field evaluation of temperature-tolerant strain of *T. japonicum* and pupal parasitoid, *Tetrastichus howardi* against sugarcane top borer, *Scirpophaga excerptalis* was carried out at IISR, farm (var. CoLk 8102). The schedule followed was: release of the egg parasitoid, *T. japonicum* @100000 adults/ha at weekly interval (at start of egg laying in each brood (*i.e.* 3 releases each in III, IV and V broods) and *T. howardi* @ 5,000adults/ha once at pupal stage in each brood and application of carbofuran @ 1kg.a.i/ha against III brood of top borer only in synchronization with pest activity (last week of June).

The pest incidence was significantly lower under bioagent release (3%) and carbofuran application (2.5%) than control (5.8%). In general, incidence of top borer was low (5.07-13.61) due to high temperature. Significantly higher cane yield was observed in bioagent (68.9 t/ha) and chemical treatment (69.7 t/ha) than in control plots (60 t/ha) (Table 31).

(b) PAU

Field evaluation of *T. japonicum* against Top borer, *S. excerptalis* was carried out at village Khera (Distt. Kapurthala) and was compared with chemical control and untreated control. 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.

Table 31. Efficacy of *Trichogramma japonicum* and *Tetrastichus howardi* against *Scirpophaga excerptalis*

Treatment	Per cent incidence	Yield (t/ha)
T. japonicum	6.04[ab]	69.72[a]
Tetrastichus howardi	7.03[b]	66.38[b]
T. japonicum +*T. howardi*	11.84[c]	68.94[ab]
Carbofuran	5.48[a]	69.71[a]
Control	13.61[d]	59.99[c]

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

The incidence of top borer in control (20.2%) was significantly higher than in release (10.2%) and chemical control plots (9.8%). The mean parasitism of eggs of *S. excerptalis* in release field was 25.3% and no parasitism was observed in chemical control. The yield in control (634.00 q/ha) was significantly lower than release fields (686.75 q/ha) and chemical control (693.75 q/ha) plots. The cost: benefit ratio in release fields was 1:7.86 as compared to 1:3.13 in chemical control.

vi) Demonstration of efficacy of *Trichogramma chilonis* for the management of *Chilo auricilius* (PAU)

The efficacy of *T. chilonis* was demonstrated over an area of 20 ha each at village Jandiala (Distt. Jalandhar) and village Karni Khera (Distt. Ferozepur) for the management of stalk borer, *Chilo auricilius*. The parasitoids were released 12 times at 10 days intervals at Jandiala and 14 times at weekly intervals at Karni Khera during July to October @ 50,000 per ha.

The incidence of stalk borer in control was 8.2% as compared to 3.1% in release field at Karni Khera, which resulted in 61.9% reduction in damage. The per cent parasitisation in release fields was high (33.6%) as compared to 5.3% in control at Karni Khera. At Jandiala, the incidence of stalk borer was 5.3% and parasitism 28.8% as compared to 13.2% and 3.9%, respectively, in control thus, resulting in reduction of incidence by 59.9%.

vii) Large-scale demonstration of biocontrol of early shoot borer with *Trichogramma chilonis* (PAU)

Large-scale demonstration of effectiveness of *T. chilonis* over an area of 3500 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 4.6 and 2.0%, respectively. The corresponding figures in control fields were 6.7 and 9.8%. The mean reduction in damage over control in both the mills was 55.5%. It can be concluded that *T. chilonis* could reduce the incidence of stalk borer by 55.5%.

viii) Population dynamics of SWA and its natural enemies

(a) TNAU

The incidence of the woolly aphid was studied in 12 different districts of Tamil Nadu. The incidence was the maximum during July and the infestation declined from July to January. Increase in the intensity of aphids was noticed during March 2006.

The experiment on population dynamics was conducted at TNAU fields on sugarcane cultivar, Co 86032. The population increased in November, but later slightly decreased in December and January. From January to March, there was a steady increase in aphid population from 42.6 to 58.0 aphids/2.5 cm^2. *Dipha* appeared in more numbers (0 to 3.6/leaf) during the months when more SWA population was noticed. *Micromus* was observed in less numbers (0 to 0.8/leaf) and no particular distribution pattern was observed.

The multiple regression coefficients of all the variables revealed that SWA population had negative correlation with maximum temperature (-0.697) and relative humidity (-0.799) and positive correlation with minimum temperature (0.444) and relative humidity (1.047). The rainfall and wind speed showed negative significant correlation with the SWA population. The weather parameters had no significant effect on *D. aphidivora* ($r^2 = 0.460$) and *M. igrotous* ($r^2=0.172$) populations. The study conducted on spatial distribution of SWA revealed the preference of the aphid to the leaves present in the top portion of the tiller (0.4-0.7) followed by middle (0.2-0.4) and bottom portions (0-0.2). The same trend was noticed with the population of *D. aphidivora* and *M. igorotus*. Even in woolly aphid-infested pockets, aphids were not recorded on paddy, sorghum, maize, hariyali, *Eichinochola crusgalli*, buffalo grass and *Cyperus rotundus*.

(b) AAU, Jorhat

The population dynamics of SWA and its natural enemies were carried out at Sugarcane Research Station, Buralikson from June to February. In ratoon crop (var. Co 740) infestation of SWA and its natural enemies was recorded from last week of June. The maximum no of SWA in 2.5 cm^2/leaf was 48 in August 2005 followed by September 2005 (45) and October 2005 (30). However, the predators viz., *D. aphidivora* (8/leaf), *Micromus* spp. (7/leaf) and Syriphids (5/leaf) were maximum during September 2005. From January 2006 the predatory activity was less. The mean number of predators recorded/leaf over the period of observations were in the order *D. aphidivora*> syrphids> *M. igorotus* (Fig. 21).

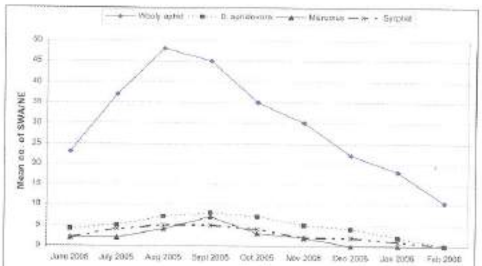

Fig. 21. Population dynamics of SWA and its natural enemies at SRS, Buralikson (Golaghat district)

The population of SWA, *Micromus* and syrphids had a significant positive correlation only with maximum and minimum temperatures, whereas *D. aphidivora* showed significant positive correlation with only maximum temperature.

(c) ANGRAU

Incidence of the pest and presence of natural enemies were 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), part of North Coastal Zone (NCZ)and Southern Zone (SZ). The overall incidence of SWA was found to be less and negligible except in one location in limited pockets of Southern Telangana Zone (STZ). Chittoor and Visakhapatnam regions recorded low incidence during November to December, 2005. There was no occurrence of *Dipha/ Micromus* due to the low to level of SWA incidence in the field. The extent of infestation and pest intensity rating ranged from nil to low and 1-3 in the different villages situated in Southern Telangana zone, Northern Telangana zone and Krishna Godavari zone.

(d) SBI

At Coimbatore, aphid numbers ranged from 0.6-2.8/leaf during October to January on var. Co 86032. Activity of *Dipha* was higher during the same period (0.6-1.1/leaf) than *Micromus* (0-0.03/ leaf).

(e) MPKV

The survey on incidence of sugarcane woolly aphid (SWA) and presence of natural enemies was conducted in major sugarcane growing areas in different agro-climatic zones of Maharashtra State during July 2005 to February 2006.

The overall infestation of SWA on sugarcane was 9.14% out of the total area of 7.1 million ha under sugarcane. Out of nine agro-climatic zones, the incidence of SWA was maximum in Western Maharashtra Plain Zone (12.47%) followed by scarcity zone (10.04%). The occurrence of *Micromus igorotus* was recorded to be high in *Kharif* season *i.e.* from August to October with its maximum population (32.5 larvae / leaf) in scarcity zone. *D. aphidivora* (2-3.6/leaf) and syrphids (1-1.8/leaf) were recorded in low levels.

(f) VSI

Survey of sugarcane fields was carried out for the incidence of SWA and its natural enemies in three zones of Maharashtra state *viz.* South, Central and North East Zone. The incidence of SWA was negligible up to August - September due to heavy rains.

In Maharashtra 49303 ha was observed to be affected by SWA and control by the predators was noticed in 40413 ha. In south zone, SWA population was sporadic and population could not build up due to immediate establishment of *Micromus* and *Dipha*. In central zone, SWA incidence in Pune and Solapur districts was scanty and *Micromus* was the predominant predator observed whereas *Dipha* population could build up after October. In Ahmednagar district, SWA incidence was low to medium since *Micromus, Dipha* and Syrphids were observed up to September. Maximum population of 54-72 larvae of *Micromus* / leaf was observed in Kisanveer SSK, Satara and Sangamner Bhag SSK, Ahmednagar. Average of 4-9 *Micromus* larvae/ leaf was noticed in Central Zone. Maximum of 8-12 *Micromus* larvae/ leaf was noticed in Tulja Bhavani SSK, Osmanabad in North East Zone. SWA incidence during the year was sporadic and intensity was low to medium. Early appearance of predators provided good control of the SWA.

ix) Biology of predators, *Dipha aphidivora* and *Micromus igorotus*

(a) TNAU

Studies on the biology of *D. aphidivora* were conducted under laboratory conditions at room temperature during July. The incubation period of the eggs ranged from 3 to 4 days with a mean of 3.27±0.44. The mean larval duration of first, second, third, fourth and fifth instars were 3.30±0.57, 3.30±0.47, 3.00±0.73, 2.40±0.59 and 2.30±0.44 days, respectively.

The prepupal duration ranged from 1 to 2 days with a mean of 1.33 ±0.44. The average pupal period was 5.60 ± 0.49 days. Mean male longevity was 3.33 ± 0.49 days, while female longevity was 5.87 ± 0.74. The total life cycle of male ranged from 25 to 27 days with a mean of 25.53 ± 1.25 days. The total life cycle of female ranged from 28 to 30 days with a mean of 28.93 ± 0.80.

Predatory potential of *Dipha aphidivora*

More number of aphids was consumed during the IV instar stage (203.4 aphids / 2.5 cm^2) followed by III (177.0) and II (130.0) instars. During its entire larval stage, the predator could consume 812.5 aphids.

(b) MPKV

The observations on life cycle of *D. aphidivora* in laboratory showed that the average hatching of eggs was 91%. There were five instars with average duration of 3.2, 3.7, 5.7, 6.5 and 5.3 days, respectively. The pre-pupal and pupal periods were 1.2 and 11.4 days, respectively. The total larval period was 24.8 days. The longevity of adults was 8.6 days. Total life cycle was completed in 54.3 days. The sex ratio was 1: 1.35 (M: F). A female laid on an average 60 eggs. A larva of *D. aphidivora* consumed 1074 ± 84 nymphs of SWA

Table 32. Biological parameters of *Micromus igorotus* on different species of aphid hosts					
Aphid species	Biological parameters				
	Egg period	Larval period	Pupal period	Adult longevity	Pre-oviposition period
A. craccivora	4.0±0.82	7.00±1.41	7.90±1.19[a]	41.30±1.19[c]	5.20±1.23[b]
P. bambusicola	3.70±0.48	7.30±1.16	6.90±0.88[ab]	44.00±2.71[b]	4.80±0.79[b]
A. gossypii	4.00±0.82	7.50±1.18	7.10±0.74[a]	46.90±3.03[a]	6.30±1.42[a]
C. lanigera	3.90±0.74	6.70±1.16	6.00±0.94[c]	34.50±3.02[d]	4.30±0.82[b]

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

or 804 ± 49 adults during its developmental period. The 4[th] instar larva fed voraciously on nymphs (865) as well as adults (662) of SWA.

(c) PDBC

Biology of *M. igorotus* was studied under laboratory conditions on four aphid species - *A. gossypii* (on cotton), *A. craccivora* (on cowpea), *P. bambusicola* (on bamboo) and *C. lanigera* (on sugarcane)

Egg period of *M. igorotus* varied from 3.7 to 4.0 days and it did not vary significantly when adults were fed with different species of aphids (Table 32). There was no significant difference in larval period (range 6.7 to 7.5 days), when different aphids were provided as host. Pupal period however varied significantly, being longer on *A. craccivora* (7.00 days) and *A. gossypii* (7.10 days) and shortest on *C. lanigera* (6.00 days).

x) Mass production of predators (*Dipha* and *Micromus*) in shade net/laboratory

(a) MPKV

Mass production under shade nets was done on the sugarcane variety Co 94012 at College of Agriculture, Pune (in February, April and May). A total of 21 shade nets were erected. The shade nets (50%) with bamboo structure of 5 x 5 x 4 m size (Fig. 22) were erected on sugarcane crop of 6, 7 and 8 months old. The SWA colonies were artificially inoculated within shade nets and inoculative release of *D. aphidivora* @ 50 larvae / pupae in each shade net was carried out.

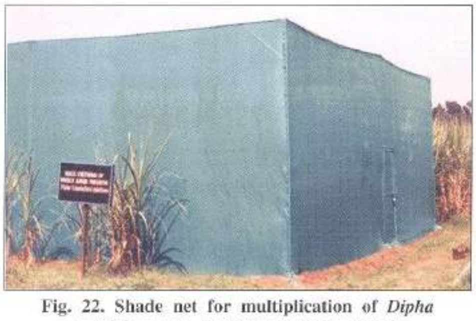

Fig. 22. Shade net for multiplication of *Dipha aphidivora* on sugarcane woolly aphid

The natural infestation of SWA was very low on the sugarcane grown in experimental field due to heavy rains. Inoculative release of the predatory larvae was carried out on 30 to 40% SWA infestation. When seven months old crop of sugarcane was used significantly more number of aphids (1230/shade net) was obtained than when six months old crop was used. The pest population did not establish in the shade nets on 8 months old crop even after repeated artificial releases of pest colonies (Table 33).

Table 33. Production of *Dipha aphidivora* in shade nets of (25 m² size)		
Age of sugarcane crop	No. of larvae / pupae of *D. aphidivora* / leaf	Total No. of *D aphidivora* larvae / pupae recovered per shade net*
Six months	0.8	270
Seven months	2.2	1230
Eight months**	—	—
Control (Uncovered)	1.2	350

* Average of 7 shade nets; ** SWA infestation could not be established

(b) SBI

A shade net of 9 x 9 x 3.6 m of 40% shade was established in the Entomology insectary. As an alternative method, the predator was reared in the laboratory in GI trays each of which was divided into three equal portions along its length. The first portion was stacked with a known numbers of aphid infested leaf bits in parallel and perpendicular rows (Fig. 23). These leaf bits were inoculated with egg-laden leaf bits containing variable eggs obtained from oviposition cages. Fresh infested leaf bits were stacked continuously in the second and third portions in the forward direction first and reverse direction next at three-day intervals to ensure enough time for predator larvae to move from drying leaves to fresh leaves. Cocoons were harvested from leaf bits in the trays between the 16th and 18th day of rearing. An infested leaf bit to egg ratio of 1:10 gave a survival rate of about 80%.

Fig. 23. Shade net used for the multiplication of *Dipha aphidivora*

(c) TNAU

Shade net production of *D. aphidivora* was carried out in Eastern block of TNAU, Coimbatore during July 2005 to January 2006. Shade net of dimension 5 x 5 x 4 m in two sections was erected when the aphid infestation reached 60 per cent. The studies revealed that *D. aphidivora* and *Micromus* colonization was dependent on the intensity of infestation of *C. lanigera* in net house. Patchiness of SWA led to reduced yield. A mean of 4.2 *Dipha* cocoons and 0.07 *Micromus* grubs per leaf could be harvested.

(d) VSI

A poly house was erected and ratoon of sugarcane var. Co 86032 was kept for SWA and *Dipha* multiplication. SWA infestation was developed by two artificial inoculations of SWA nymphs and adults at monthly interval. A temperature of 28°C and relative humidity of 75% was maintained in the polyhouse during tillering phase. A total of 2,92,000 larvae and winged adults of SWA were released in two installments into the poly house. SWA establishment was observed in 25-30 days with maximum of 105 SWA in 2.5 cm^2. Effect of shade net percentage on development of SWA and predators was studied in var. Co 86032. Maximum of 2.20 larvae of *Dipha* /leaf was noticed in 40 and 50% shade nets. Development of *Dipha* was observed to be faster in 50 per cent shade net as compared to 40 per cent shade net. Maximum of 1.0 larva of *Micromus* / leaf was recorded in 50 per cent shade net, while in 40 per cent shade net it was a maximum of 2.40.

(e) PDBC

Biological parameters like feeding potential and fecundity of *M. igorotus* were studied by using four aphid species *viz*., *A. gossypii*, *A. craccivora*, *P. bambusicola* and *C. lanigera* to identify the best host for rearing. *Micromus igorotus* laid maximum number of eggs when reared on *P. bambusicola* (799.9 eggs/female) while it was the least when *C. lanigera* was used as host (590.2 eggs/female) and the adults got entangled into mealymass of *C. lanigera* at the base of rearing containers. There was no significant difference in the fecundity obtained on *A. gossypii* (654.40 eggs/female) and *A. craccivora* (662.2 eggs/females). Even though it laid maximum number of eggs when fed with *P. bambusicola*, feeding potential was least (561.1 aphids/adult) on this species. On the other hand, maximum feeding was on *A. gossypii* (2019.1/ adult), while it yielded least number of eggs. *Aphis gossypii*, which is smallest in size was fed upon in larger quantity while *P. bambusicola*, largest amongst the species provided, was fed upon in least number. The predators laid 35.5% times more number of eggs when *P. bambusicola* was used as prey as compared to *C. lanigera*. Per cent increase in fecundity was 12.2 and 10.9% on *A. carccivora* and *A. gossypii*, respectively, as compared to *C. lanigera*.

xii) Effect of Agronomic Practices on the incidence of SWA (MPKV)

The experiment was carried out on the research farm of Central Sugarcane Research Station, Padegaon on var. Co 86032. The treatments included were

T_1: Agronomic package: Paired row of 75 cm between rows and 150 cm between pairs, optimum water use, nitrogenous fertilizer normal dose (225N:115P:115K) with 25 % through organic sources and 75% through inorganic sources, intercrop (cabbage) and border row of cowpea and removal of leaves with initial infestation.

T_2: Farmer's practice: Rows of 75 cm distance, frequent irrigation, nitrogen dose 1.5 times more than normal dose/ha, no intercrop, de-trashing and removal of the trash from the plots and removal of leaves with initial infestation.

Agronomic package and farmers' practice were comparable with respect to aphid infestation (15.6 and 18.2%, respectively) and natural predator population (0.3 and 0.2/leaf, respectively). The yield data were non significant (76.5 and 74 t/ha, respectively under recommended and farmers' practice).

xiii) Field release and evaluation of *D. aphidivora* and *M. igorotus*

(a) TNAU

A field study on the efficacy of *Dipha* was conducted in the farmer's field at Vellalore. Four spots of 0.25 ha size were selected with the following conditions.

i. Heavy infestation of SWA with natural occurrence of *Dipha*
ii. Initial infestation of SWA with natural occurrence of *Dipha*
iii. Initial infestation of SWA and no natural occurrence of *Dipha*
iv. Initial infestation of SWA without the natural occurrence of *Dipha* + inoculative release of *Dipha*.

The predator was released @ 1000/ha and the second release after 10 days. The predator exercised up to 97.2% control in *Dipha* released plots after four months. Irrespective of SWA incidence level, 100% reduction in aphid population was achieved five months after release. No new incidence of sugarcane woolly aphid was observed during 6^{th} and 7^{th} months after release.

(b) SBI

Predator cocoons obtained from laboratory cultures were released in an experimental plot at the rate of 1000 per ha. A control plot was maintained in a different location. Mean aphid rating showed a significant (t=3.13; P<0.01) decrease from 3.3 before release to 2.5 after release, amounting to a 25.2% decrease within a month. During the same period, *Dipha* numbers showed more than 20-fold increase from 0.3 before release to 6.7 after release. *Micromus* was rarely encountered and its numbers per leaf remained at 0.1 before and after release of *Dipha*. In contrast, in the control plot without predator release, aphid rating and *Dipha* numbers per leaf remained constant over the corresponding 30-day period.

In the Institute campus, 787 adults of *Micromus* were released in a 0.1 ha area of about 1 ha plot with established *Dipha* colonies but no *Micromus* activity. Mean rating of aphid per leaf (2.29) before predator release did not differ significantly from the rating (2.26) obtained one month later. There was a marginal increase in *Micromus* numbers from zero per leaf to 0.1 per leaf during the same period. Activity of *Dipha* was same before and after the release of *Micromus*. A second observation 15 days later did not reveal any *Micromus* activity indicating its failure to establish.

xiv) Interaction between *D. aphidivora* and *M. igorotus* (TNAU, PDBC and ANGRAU)

(a) TNAU

Dipha and *Micromus* were released in the ratios of 1:0; 1:1; 1:2; 1:3; 1:4; 0:1; 2:1; 3:1 and 4:1 and aphids provided *ad libitum*. The results showed that there was no competitive elimination of either of the predator at different densities and both were able to survive in the same niche without exerting negative effect on the other (Table 34).

Table 34. The interaction of *Dipha aphidivora* and *Micromus igorotus*

Ratio of natural released enemies (*Dipha:Micromus*)	Prerelease count (Aphid)	Post count				Percentage of natural enemies pupated	
		I day	II day	III day	IV day	*Dipha*	*Micromus*
1:0	150	123	121	91	93	100	0
1:1	150	137	136	98	92	100	100
2:1	150	121	128	96	98	100	100
3:1	150	132	132	93	99	100	100
4:1	150	128	137	97	97	75	100
0:1	150	139	123	93	96	0	100
1:1	150	134	141	95	95	100	100
1:2	150	124	143	96	94	100	50
1:3	150	127	135	98	93	100	66.6
1:4	150	143	133	92	92	100	75

(b) PDBC

Laboratory studies were conducted to study the interaction of different stages of *M. igorotus* with different stages of *D. aphidivora*. When confined in the laboratory in the absence of the sugarcane woolly aphid, adults of *M. igorotus* fed on first and second instars of *D. aphidivora*. Third instars of *M. igorotus* were also capable of feeding on *Dipha*. Dipha eggs were not fed upon by any of the stages of *Micromus*. Conversely, second and later instars of *Dipha* fed on eggs and all instars of *Micromus*.

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

(a) TNAU

The trial was conducted in a hot spot area, in the farmer's field at Vellalore. One thousand larvae of *D aphidivora* were released. Another field was also selected for comparison in which the farmers practice (Sequential dusting methyl parathion (10 D) by using a cloth bag, synthetic pyrethroid after two weeks and a spray of synthetic pyrethroid) was adopted. Initial aphid population and pest intensity rating as well as predators on leaf and subsequent observations at 15 days interval indicated that biocontrol was effective as the farmers' practice (Table 35).

(b) MPKV

The field experiment was conducted on a research farm on sugarcane var. Co 94012. Inoculative release of *D. aphidivora* @ 1,000 larvae/ha was carried out, whereas in farmers' practice, the predator was not released.

Inoculative release of *D. aphidivora* @ 1,000 larvae/ha, significantly reduced the SWA population within 45 days (4.7/2.5cm^2/leaf) as compared to farmers practice (12.3/2.5cm^2/leaf). At 60 days after release no SWA population was observed. At harvest, yield data were non significant (93.5 and 90.1 t/ha, respectively).

Table 35. Field demonstration of biocontrol using *Dipha aphidivora*

Particulars	Pre-treatment count	Months after release (Post count)			
		I	II	III	IV
		Dipha released plot			
Aphid / 2.5 cm ^{2}	92	75	52	28	06
Dipha / leaf	1.8	1.2	1.4	1.2	0.2
Pest intensity rating	5	3	3	2	1
		Farmers' field			
Aphid / 2.5 cm ^{2}	98	85	78	86	92
Dipha / leaf	1.7	1.6	1.4	0.8	1.0
Pest intensity rating	5	5	5	5	5

xvi) Development of IPM strategy (IISR)

Planting of cane at wider row space (45:120 cm) proved superior to the conventional planting (75 cm distance) to minimize the intensity of SWA infestation.

With the help of cane development workers of sugar mills and farmers, conservation of natural enemies and redistribution of predators from high density area to low density area proved successful around Khatauli and Deoband Sugar Mill areas of Uttar Pradesh.

xvii) Colonization of *Encarsia flavoscutellum*

(a) MPKV

Consignments of *Encarsia* obtained from PDBC were released in fields heavily infecsted with SWA. After 15 days of release, only 6 adults were recovered.

(b) VSI

A shade net (50%) was erected on 20 sq. m area over seven-month-old sugarcane crop, which was already infested by SWA. The leaf pieces containing SWA nymphal colonies, which were already parasitised by *Encarsia* were released in the shade net along with 18 adults of *Encarsia*.

Before release of *Encarsia*, mean SWA population recorded was 124 nymphs and adults per 2.5 cm^2. At 22 days after release (DAR) of *Encarsia*, SWA population declined to 97.8 and at 45 days DAR it reduced to 36.5 nymphs and adults per 2.5 cm^2. An average of 4 adults of *Encarsia* per leaf was observed at 22 DAR and reached a peak of 8.2 adults per leaf. With decline in population of SWA at 45 DAR adult recovery was reduced to 5.4 per leaf. *Encarsia* adult recovery ranged from minimum of two-adults/leaf to maximum of 11 adults per leaf at 30 DAR. After 55 days, sugarcane in shade net was completely free from SWA incidence.

xviii) Monitoring and forecasting of SWA (IISR)

Observations on population of sugarcane woolly aphid and its natural enemies in relation to abiotic factors were made at weekly intervals from ratoon crop (after first appearance of SWA colony) with CoS 767 variety. Maximum SWA (up to 265.4 (nymphs + adults) and *D. aphidivora* population (3.8 larvae/2.5 cm^2/infested leaf) were recorded during 43rd std. week (last week of October, 05). SWA population gradually decreased from 44th std. week (first week of November, 05) up to 4th std. week (last week of January, 06) and *D. aphidivora* population during this period was recorded to be 7.3 larvae/infested leaf. *Metasyrphus confrator, M. igorotus*, and coccinellids, *viz., Coccinella septumpunctata* were also observed feeding on SWA.

There was a significant positive correlation (r=0.905) between maximum temperature and aphid population (18.5°C-33.6°C). *Dipha aphidivora* population showed significant negative correlation (r=-0.802) with the aphid population. SWA population positively correlated (r=0.305) with the rainfall however, negative correlation (r =-0.309) was observed between *D. aphidivora* population and rainfall (0.0-250.2 mm.). There was a significant positive correlation (r=0.786) between *M. igorotus* population and maximum temperature (18.5°C-33.6°C), but it was negatively correlated (r=-0.518) with *D. aphidivora*.

xix) Yield loss assessment

(a) SBI

The study was made on sugarcane var. Co 86032 of six-months age with SWA infestation and with un-infested canes of equal number serving as control. Growth rate of infested canes was significantly lower than that of healthy canes in the first fortnight following attack in either fifth (Table 36) or sixth month of age. In subsequent six fortnightly observations, there was no difference in growth rate between infested and healthy canes. These observations suggested a possible initial effect of aphid attack on cane growth and the subsequent recovery of the cane.

Cane samples from the study area were examined at harvest for yield and quality parameters of juice. Cane weight, juice weight, brix and sucrose were significantly affected when infestation occurred at sixth month but not at fifth month (Table 37). Attacked canes showed higher potassium content. In jaggery analysis, sucrose was significantly lower (75.9-76.8%) and reducing sugars (12.25-14.5%) were significantly higher in infested canes. Other parameters in both sugar and jaggery analysis showed variable trend.

Table 36. Effect of woolly aphid on linear growth of sugarcane when infestation occurred in fifth month			
Fortnight after marking canes	Cane growth over initial measurement (%)		t-value
	Infested cane	Healthy cane	
1	16.8	23.0	4.77^{***}
2	36.8	35.5	0.76^{ns}
3	57.7	54.9	1.23^{ns}
4	78.9	76.0	0.98^{ns}
5	102.8	101.3	0.41^{ns}
6	126.4	126.1	0.07^{ns}
7	139.6	142.6	0.65^{ns}

Table 37. Effect of woolly aphid on yield and juice quality parameters when infestation occurred in sixth month			
Parameter	Infested cane	Healthy cane	t-value
Cane weight (kg/5 canes)	3.8	4.7	4.24^{***}
Juice weight (kg/5 canes)	1.5	1.9	3.29^{**}
Ext %	38.0	40.1	1.18
Brix %	20.3	19.0	3.76^{**}
Sucrose %	17.8	16.6	3.33^{**}
Purity %	87.4	87.6	0.25
EC (mmhos/cm)	8.5	8.4	0.42
Acidity	1.2	1.0	3.43^{**}
RS %	0.7	0.7	0.06
N (mg/100ml)	28.7	35.8	2.08
P (mg/100ml)	319.8	241.3	8.07^{***}
K (mg/100ml)	386.5	352.0	3.12^{**}
Amino acid (mg/100ml)	77.8	63.0	0.94
Phenols (mg/100ml)	40.6	39.4	0.28

(b) IISR

Quantitative and qualitative losses were worked out from the severely infested canes of CoS 767, CoS 8432, CoS 8436, CoPt 84212, CoS 88230 and CoJ 64 varieties. Per cent loss in sugar recovery and weight ranged from 10.0 (CoS 8436) to 19.80 (CoS 767) and 10.56 (CoS 8436) to 20.5 (CoS 767), respectively.

Field wise area of infestation ranged from 0.6 to 35.0 per cent (Average 13.4%). Maximum fields were found to be infested in south direction (50%) followed by west (25%), whereas, infestation in both North and East direction was 18.8 per cent. In centre, only 12.5 per cent fields were infested with SWA.

xx) Effect of insecticide application on the development of SWA predators (VSI)

Effect of insecticide application on the development of SWA predators was studied at Yeshwant (T) SSK, Pune in Manjari area on var. Co 86032. Methyl parathion 2% dust @ 40 kg/ha was applied on 02-06-2005 to control the SWA population and the observations on SWA population and number of predators/leaf were recorded at weekly interval.

Immediately after the application of insecticide, the SWA incidence was reduced to nil. However, the incidence restarted 30 days after the application of insecticide and the predator development started 60 days after insecticide application (Table 38). Predator development was low and scanty in the treated field. The SWA incidence in the field without insecticide application was controlled with timely development of *Micromus* and *Dipha*. Maximum of 6.00 larvae of *Micromus* per leaf was noticed in the field.

3.5. BIOLOGICAL SUPPRESSION OF COTTON PESTS

i) BIPM for *Bt* cotton (ANGRAU, AAU (A), TNAU, MPKV, UAS (D) and PAU)

Biocontrol-based IPM modules were evaluated during kharif 2005 in different locations. The different modules tested are as follows:

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 *Chrysoperla carnea* @ 14,000 /ha once at initial aphid build up stage; spray of *Sl* NPV @ $3x10^{12}$ POBs /ha for *Spodoptera litura*. Application of *Sl* NPV mixed with 0.5% crude sugar as UV protectant and surfactant, when larvae are in 1st to 3rd instar stage; sowing non *Bt* cotton as refugia as recommended; erection of bird perches @ 10/ha.

Module II: BIPM + non-*Bt* Cotton

In addition to the practices mentioned in module I, the following practices were included: release of *Trichogramma 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 1st to 3rd instar larval stage of *H. armigera*.

Module III: Farmers' practice (FP) +*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 imidacloprid 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.

Table 38. Record of woolly aphid, *Dipha aphidivora* and *Micromus igorotus* in insecticide- sprayed and control field

Date of observation	Average population per leaf					
	Insecticide sprayed field			Natural field		
	SWA	*Dipha*	*Micromus*	SWA	*Dipha*	*Micromus*
17.05.2005	34.22	0.00	0.00	43.00	0.00	0.00
26.05.2005	43.00	0.00	0.00	37.80	0.00	0.00
31.05.2005	40.60	0.00	0.00	29.40	0.80	3.80
07.06.2005	2.40	0.00	0.00	27.60	1.60	6.00
14.06.2005	0.00	0.00	0.00	6.40	0.60	2.40
22.06.2005	0.00	0.00	0.00	0.00	0.00	0.00
28.05.2005	0.00	0.00	0.00	0.00	0.00	0.00
05.07.2005	9.40	0.00	0.00	0.00	0.00	0.00
13.07.2005	35.00	0.00	0.00	15.00	0.60	1.20
21.07.2005	27.80	0.00	0.00	24.80	0.20	4.40
01.08.2005	35.60	0.00	0.00	24.60	0.00	2.60
10.08.2005	38.40	0.40	0.40	4.00	0.00	0.00
17.08.2005	38.20	0.60	1.00	0.00	0.00	0.00
23.08.2005	31.20	0.60	1.20	0.00	0.00	0.00
08.09.2005	28.40	0.00	0.80	0.00	0.00	0.00
20.09.2005	36.60	0.00	0.60	0.00	0.00	0.00

Module IV: Farmers' practice (FP) +non-*Bt* Cotton

It consisted of imidacloprid-treated seeds; local practice by farmers was also advocated.

ANGRAU

The experiment was laid out at the Agricultural Research Station, Warangal (AP). Maximum number of aphids (128.20 /5 plants), jassids (42.50 /5 plants) whiteflies (61.40 /5plants) was noticed in the module consisting of *Bt* cotton + FP. The sucking pest population was more in *Bt* cotton grown under Farmers practice (FP) module while least population was recorded in *Bt* cotton grown under BIPM module. Maximum square and boll damage by bollworms was noticed in non-*Bt* + FP while the least damage was noticed in *Bt* + BIPM.

Egg parasitism in different test modules did not differ significantly among the different modules. Trends, however, have shown that least egg parasitism (0.40%) was found in non-*Bt* + FP while maximum of 3.08% was recorded in *Bt* cotton + BIPM. Maximum number of coccinellids, (12.80 to 20.80 /50plants), were noticed in both *Bt* and non-*Bt* with BIPM while they were as low as 0.80 to 2.00 /50 plants in both *Bt* and non *Bt* grown under FP module (Table 39).

Maximum yield of 3100 Kg/ha was recorded in *Bt* cotton + BIPM combination followed by 2300 Kg/ha in *Bt* cotton + Farmer's practice. Non-*Bt* cotton with BIPM package recorded 2200 Kg/ha. non-*Bt* cotton with farmer's practices recorded least yield of 2000 Kg/ha. *Bt* cotton was capable of minimizing the damage by boll worm to a greater extent. *Bt* cotton with BIPM gave good yield returns as compared to other modules (Table 39).

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Bt cotton + BIPM package recorded significantly lower bud (3.9%) and boll damage (3.8%) as compared to non *Bt* cotton + BIPM (14.0 and 21.6%, respectively) followed by non-*Bt* Cotton + GAU schedule (15.5 and 23.6%, respectively).

Bt cotton + BIPM package also recorded lower locule damage (4.9%) due to *E. vittella* and *P. gossypiella*, followed by non *Bt* cotton + GAU schedule (20.2 and 28.8%) and *Bt* cotton + existing practice (5.7 and 6.2%, respectively). There was significant reduction in the population of aphid, jassid and whitefly in case of *Bt*. Cotton + BIPM as compared to non-*Bt* cotton.

The seed cotton yield was also higher in *Bt* cotton + BIPM (2681 kg/ha) as compared to non-*Bt* cotton + BIPM (2056 kg/ha) and non *Bt* cotton + GAU schedule (1736 kg/ha), respectively. The population of various natural enemies was high in case of *Bt* cotton + BIPM and non-*Bt* cotton + BIPM package compared to other two treatments indicating adverse effect of insecticides used in the package.

TNAU

The trials were conducted at Putur, Coimbatore (2005 to 2006). The *Bt* + BIPM cotton recorded less *H. armigera* population (0.28 larvae/ plant) followed by *Bt* FP cotton (0.30). The *Bt* + BIPM cotton recorded less *Earias* population (0.06 larvae / plant) followed by *Bt* FP cotton (0.07) (Table 40). Highest larval population was recorded in non *Bt* cotton + FP.

Bollworm damage

The per cent fruiting body damage in different modules was in the order of *Bt* BIPM < *Bt* FP < non-*Bt* BIPM < non-*Bt* FP.

Table 39. Efficacy of BIPM and farmers' practice (FP) in *Bt* cotton in ANGRAU

Treatment	Mean damage (%)		Yield (q/ha)	Egg parasitism (%)	Predators (No./50 plants)	
	Squares	Bolls			Coccinellids	Spiders
Bt cotton + BIPM	6.4[a]	5.7[a]	31.0	3.0	12.8[b]	3.4[b]
Non-*Bt* cotton + BIPM	31.8[c]	19.7[c]	22.0	1.6	20.8[a]	20.8[a]
Bt cotton + FP	20.8[b]	9.0[b]	20.0	1.6	2.0[c]	2.0[c]
Non-*Bt* cotton + FP	40.2[d]	28.0[d]	23.0	0.4	0.8[d]	1.6[c]

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

Incidence of sucking pests in different IPM modules

The incidence of leafhoppers in different modules ranged between 2.49 to 5.31 per plant. The *Bt* cotton with farmers' practice recorded lowest incidence of hopper (2.49) followed by *Bt* with BIPM module (3.07). The incidence of aphids was least in *Bt* with FP module. The number of aphids in different modules ranged from 2.13 to 5.57 per plant. The number of thrips per plant in different modules was 1.39, 1.49, 1.02 and 2.41 in *Bt* BIPM, non *Bt* BIPM, *Bt* FP and non *Bt* FP, respectively. The mean number of whiteflies ranged between 0.96 and 2.10 per plant in different modules. The lower incidence of sucking pest population was recorded in *Bt* FP module.

The *Bt* cotton protected with BIPM module recorded higher yield (1865 kg / ha), in comparison to FP module (1798 kg / ha). *Bt* cotton under BIPM or FP performed better in reducing the bollworm damage and providing higher seed cotton yield (Table 40).

Occurrence of natural enemies

The BIPM modules recorded significantly higher number of natural enemies than the FP modules. The order of occurrence of lacewings in Puthur trial was *Bt* BIPM>non-*Bt* BIPM>*Bt* FP>non-*Bt* FP (0.51>0.47>0.34>0.16/plant). The coccinellids, which were predominant during the field studies were *Cheilomenes sexmaculata* and *Coccinella transversalis*. The order of occurrence of coccinellids in the different modules was *Bt* BIPM>non-*Bt* BIPM>*Bt* FP>non-*Bt* FP (2.45>1.18>0.96>0.78/plant). The occurrence of spiders (*Oxyopes* spp., *Argiope* spp., *Neoscona* spp., *Araneus* spp. and *Plexippus* spp.) was higher in BIPM modules than in FP modules.

MPKV

The experiment was laid out at the research farm of Agronomy section, College of Agriculture, Pune.

Bt cotton with existing recommended package of practices was the most effective in suppressing the population of aphids, jassids, thrips and white flies. The population of predators, viz. coccinellids, *C. septempunctata*, *C. sexmaculata* and chrysopid, *Chrysoperla carnea* were maximum in the plots of *Bt* cotton with BIPM package. Maximum kapas yield was recorded in the treatment plots of *Bt* cotton with existing package, followed by *Bt* cotton with BIPM package (Table 41).

UAS (D)

The incidence of aphid was more in existing package of practices (RPP) in both *Bt* (6.2/5 leaves) and non-*Bt* cotton (6.4/5 leaves) and were on par with each other. In BIPM, the population was significantly less both in *Bt* (3.5/5leaves) and non-*Bt* 3.5/5leaves). The highest leafhopper population (9.20/5 leaves) was observed in *Bt* cotton +BIPM module followed by non-*Bt* cotton+BIPM module (7.8). The increasing order of thrips population in different modules was non-*Bt* cotton+RPP<*Bt* cotton+RPP<non-*Bt* cotton+ BIPM< *Bt* cotton+BIPM. There was negligible incidence of whiteflies recorded in different modules during the season (Table 42). The observation on damage to fruiting bodies due to bollworms clearly indicated less incidence on RCH 2 *Bt* cotton (3.1%) as compared to RCH 2 Non-*Bt* cotton (17.4%). The highest good opened bolls (16.4/ plant) was recorded in *Bt* cotton+BIPM module followed by *Bt* cotton+RPP (17.3) module. Higher yields were recorded in these two treatments (1400.5 and 1080.5 kg/ha, respectively).

Table 40. Incidence of bollworm damage in different modules at Puttur (2005 -2006)

Modules	Mean larval population / plant		Bollworm damage (%)				Yield (kg/ha)
	H. armigera	*E. vitella*	Fruiting bodies	Open boll	Locule	Inter locule	
Bt – BIPM	0.28^{a}	0.06^{a}	1.25^{a}	0.54^{a}	0.22^{a}	0.28^{a}	1865^{a}
Non-*Bt* – BIPM	0.40^{c}	0.16^{c}	2.39^{c}	0.96^{c}	0.68^{c}	0.92^{c}	1590^{c}
Bt – FP	0.30^{b}	0.07^{b}	1.73^{b}	0.71^{b}	0.28^{b}	0.34^{b}	1798^{b}
Non-*Bt* – FP	0.61^{d}	0.68^{d}	5.88^{d}	1.95^{d}	1.36^{d}	1.50^{d}	1392^{d}

Means of fifteen observations; Means followed by similar letters are not significantly different (P=0.05) by LSD

Table 41. Effect of BIPM practices on pest complex, natural enemies and yield of *Bt* cotton

Treatment	Sucking pest population (number/3 leaves)*				NEs population (Number/plant)*		% damage by bollworms**		Yield of kapas (kg/ha)
	Aphids	Jassids	Thrips	White flies	Coccinellids	*C. carnea*	Squares	Bolls	
Bt cotton with BIPM package	12.4^{a}	3.0^{a}	10.4^{b}	2.1^{b}	5.2^{a}	6.2^{a}	0.7^{a}	0.5^{a}	1345^{a}
Non-*Bt* cotton with BIPM package	15.0^{b}	4.3^{c}	10.4^{b}	2.5^{b}	4.8^{a}	5.2^{a}	2.1^{b}	2.6^{c}	1005^{b}
Bt cotton with existing package	12.0^{a}	2.2^{a}	8.5^{a}	1.5^{a}	4.9^{a}	5.6^{a}	0.9^{a}	1.1^{b}	1415^{a}
Non-*Bt* cotton with farmers practice	17.6^{c}	3.3^{b}	11.9^{c}	2.8^{c}	4.9^{a}	3.9^{b}	10.4^{c}	9.2^{d}	825^{c}

Means followed by similar alphabets do not differ significantly; Means of observations recorded at 15 days interval on 5 plants from each of 10 replications

Table 42. Incidence of sucking pest population in different modules

Treatment	Number of sucking pests per five leaves			
	Aphids (60 days after sowing)	Leaf hoppers (60 days after sowing)	Thrips (75 days after sowing)	Whiteflies (135 days after sowing)
Bt cotton + BIPM	3.48^{a}	9.20^{d}	4.32^{c}	2.28^{b}
Non-*Bt* cotton + BIPM	3.50^{a}	7.82^{c}	3.66^{b}	1.68^{ab}
Bt cotton + RPP	6.20^{b}	4.08^{b}	2.14^{a}	1.18^{ab}
Non-*Bt* Cotton + RPP	6.36^{b}	2.92^{a}	1.52^{a}	0.38^{a}

Means followed by similar alphabets do not differ significantly

More number of natural enemies, *viz*., coccinellids, spiders, *Chrysoperla carnea* and anthocorids were recorded in BIPM module (irrespective of the cultivars) in comparison to RPP module.

PAU

The experiment on BIPM of *Bt* cotton was conducted at two locations *viz*., Karni Khera and Khuban (Distt. Ferozepur) by taking three *Bt* and three Non- *Bt* hybrids, namely RCH 134, MRCH 6301 and Ankur 651.

The mean population of cotton jassids and whiteflies recorded on the various hybrids of *Bt* and non-*Bt* cotton at Karni Khera and Khuban villages in IPM and BIPM plots (Tables 43 and 44). In general the population was low in both IPM and BIPM plots

The fruiting bodies damaged in *Bt* hybrids at both the locations was negligible and also there was no damage observed in case of Non- *Bt* hybrids at Karni Khera but at Khuban mean fruiting body damage on Non- *Bt* hybrids with Farmer's practices and BIPM was 0.4 and 0.4% on RCH 134 Non-*Bt*, 0.5 and 0.5 on MRCH 6301 Non-*Bt*, 0.5 and 0.5 on Ankur 651 Non-*Bt*. Maximum yield was obtained in IPM practices with RCH 134 hybrid at village Karni Khera and Khuban (32.7 q/ha and 29.5 q/ha) followed by MRCH 6301 (27.9 q/ha and 26.7 q/ha). No significantly difference was observed among 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.

Table 43. BIPM of *Bt* cotton at Karni Khera village (Distt. Ferozepur)

Variety		Jassids per 5 leaves		Whiteflies per 5 leaves		Yield (q/ha)	
		IPM	BIPM	IPM	BIPM	IPM	BIPM
RCH 134	*Bt*	0.39	0.33	2.09	2.25	32.7	31.2
	Non-*Bt*	050	0.56	2.32	2.02	28.7	28.5
MRCH 6301	*Bt*	0.38	0.40	1.88	1.77	27.9	27.3
	Non-*Bt*	0.72	0.66	2.36	2.22	25.5	24.9
Ankur 651	*Bt*	0.31	0.31	1.73	1.68	21.0	19.2
	Non-*Bt*	0.50	0.48	1.60	1.72	17.4	17.0

Table 44. BIPM of *Bt* cotton at Khuban village (Distt. Ferozepur)

Variety		Jassids per 5 leaves		Whiteflies per 5 leaves		Fruit body damage (%)		Yield (q/ha)	
		IPM	BIPM	IPM	BIPM	IPM	BIPM	IPM	BIPM
RCH 134	*Bt*	0.59	0.50	0.72	0.85	-	-	29.5	28.8
	Non-*Bt*	0.68	0.72	0.84	0.75	0.40	0.43	22.3	23.8
MRCH 6301	*Bt*	0.60	0.53	0.81	0.75	-	-	26.7	24.4
	Non-*Bt*	0.79	0.65	0.94	0.84	0.50	0.49	19.1	19.8
Ankur 651	*Bt*	0.66	0.54	0.74	0.65	-	-	20.6	08.6
	Non-*Bt*	0.57	0.70	0.76	0.75	0.51	0.51	16.8	16.5

ii) Natural enemy complex of all pests including bollworms *Spodoptera litura,* sap sucking pests and other bugs in *Bt* & non-*Bt* cotton varieties & hybrids

ANGRAU

The experimentation was taken up in Gorrupadu village of Warangal district. A total of 5 *Bt* cotton hybrids *viz.*, RCH-2 and 20, Bunny, Mallika and Pro Agro-368 were observed during the experimentation and compared with non-*Bt* cotton of the above *Bt* hybrids.

The sucking pest population was in general more in *Bt* cotton hybrids compared to non-*Bt* cotton hybrids, whereas *Bt* cotton fared better than their non-*Bt* counterparts with respect to square and boll damage. The incidence of *S. litura* was noticed in the areas where bollworm populations were on the decline. Egg parasitism was negligible and activity of predator was lesser in *Bt* cotton hybrids when compared with non-*Bt* counterparts.

AAU, Anand

The experiment was carried out at Anand on *Bt* cotton RCH-2, G.cot Hy. 8 and G.cot Hy.10 and comprised of treatments like *Bt* cotton (RCH-2) with imidacloprid seed treatment; *Bt* cotton (RCH-2) without imidacloprid; G. Cotton Hy. 8 and G. Cotton Hy.10.

Bt variety with imidacloprid seed treatment recorded significantly lower sucking pest population per 15 leaves. The number of aphids (3.3), jassids (2.1) and whiteflies (1.8) were significantly lower than in *Bt* cotton without imidacloprid seed treatment (4.6, 2.4 and 1.9, respectively), Hy. 8 (6.3, 2.9 and 2.3, respectively) and Hy.10 (5.7, 2.7 and 2.0, respectively). The same trend was also recorded for bud and boll damage.

Seed cotton yield was highest in *Bt* cotton with imidacloprid seed treatment (2486 kg/ha) followed by *Bt* cotton (2311 kg/ha) without imidacloprid seed treatment, Hy.8 (1622 kg/ha) and Hy. 10 (1856 kg/ha), indicating suppressive effect of imidacloprid on sucking pest complex.

Bt cotton with imidacloprid seed treatment had higher population of *C. carnea*, *C. sexmaculata*, *Geocoris* and staphylinid in comparison to *Bt* cotton without imidacloprid seed treatment, G.Cot 8 and G.Cot 10. Both *Bt* cotton treatments recorded lower *Rogus* and *T. chilonis* population as compared to Hy. 8 and Hy. 10.

iii) Enhancement of natural enemy population in cotton by habitat manipulation

PAU

The experiment on enhancement of natural enemies population in cotton by habitat manipulation was conducted at Entomological Farm, PAU, Ludhiana.

The following three models 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* @1,50,000/ha were made at weekly interval 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 21-8-05 for the control of cotton jassid; two sprays of deltamethrin (2.8 EC) @400ml/ha (one on 24-8-05 and second on 10.9.05) against spotted bollworm (*Earias* sp.).

Jassid population in all the treatments was at par in August. However, after the insecticidal application, it was significantly lower in insecticidal control plot (0.3-1.1 nymphs/3 leaves).

Mean jassid population was significantly lower (1.4 nymphs/3leaves) in the insecticidal control plot as compared to habitat management (4.7 nymphs/3 leaves) and BIPM (4.5 nymphs/3 leaves) plots. The white fly remained below ETL (18 adults/ 3 leaves) throughout the season.

There was no incidence of *H. armigera*. However, incidence of spotted bollworm was significantly lower in insecticidal treatment plot on all the dates of observation (after insecticidal spray). Lowest mean bollworm incidence (2.6%) was recorded in insecticidal control and it was significantly lower than habitat management (5.1%) and BIPM (5.1%). Bollworm incidence in habitat management and BIPM was at par. Similarly lowest bollworm incidence (0.8 - 1.0%) among green bolls was recorded in insecticidal control plot The mean bollworm incidence among green bolls in habitat management (3.9%) and BIPM (3.9%) was at par. Natural enemies population was higher (0.8 per plant) in habitat management plot followed by BIPM (0.7 per plant) and was very low in insecticidal control (0.1 per plant). Highest seed cotton yield (14.8 q/ha) was recorded in insecticidal control plot and it was significantly higher than habitat management (11.2 q/ha) and BIPM (11.1 q/ha).

AAU, Anand

The experiment was conducted at Anand using and the treatments included are

T1: Treating cotton seed with *Trichoderma* @ 5.0 g/kg, cotton interspersed with *Cassia occidentalis* (6:1) + 10 % planting of maize, zinnia + one release of *Trichogramma chilonis* @ 1,50,000 + 5000 larvae of *Chrysoperla carnea*.

T2: Treating cotton seeds with *Trichoderma* @ 5..0 g / kg, cotton interspersed with *Cassia occidentalis* (6:1) + 10 % planting of maize, zinnia.

T3: Insecticidal control

T4: Untreated control

The IPM treatment involving the release of bioagents recorded significantly lower aphid, jassid and whitefly population followed by IPM without release of bioagents and insecticidal treatment. The same trend was observed in case of bud and boll damage caused by *E. vittella* or *P. gossypiella* (Table 45).

Higher yield was recorded in IPM+ bioagent release plot (2031 kg/ha). Population of *C. carnea*, *C. sexmaculata*, *Geocoris*, Staphylinids, *Rogas* and *T. chilonis* were also higher compared to other treatments indicating additive as well as beneficial effect of habitat manipulation.

Table 45. Number of sucking pests, bollworm damage and yield								
Treatment	Sucking pests/15 leaves			% Damage by boll worms				Yield (kg./ha)
	Aphid	Jassid	W.fly	*E. vittella*		Locules		
				Bud	Boll	*Ev*	*Pg*	
IPM+Tc+Cc 6:1	13.3[a]	2.3[a]	2.2[a]	7.6[a]	11.9[a]	12.5[a]	14.2[a]	2031[a]
IPM 6:1	21.7[b]	4.5[b]	3.5[b]	8.1[b]	12.9[b]	13.2[a]	15.0[b]	1972[a]
Insecticide	23.6[c]	5.4[c]	3.7[c]	8.4[b]	14 3[c]	14.6[b]	23.6[c]	18.69[a]
Control	97.9[d]	9.1[d]	6.6[d]	17.1[c]	2 4.5[d]	31.6[c]	32.4[d]	1308[b]

Means followed by common letter are not having significant differences (P=0.05) by DMRT; *Ev: Earias vittella; Pg: Pectinophora gossypiella*; Tc: *T. chilonis;* Cc: *C. carnea;* IPM: Integrated pest management

3.6. BIOLOGICAL SUPPRESSION OF TOBACCO PESTS

i) Biological control of *Spodoptera exigua* in tobacco nurseries with biopesticides (CTRI)

The treatments included were *Nomuraea rileyi* (10^{13} spores/ha), NSKE (2 %), *Beauveria bassiana* (10^{13} spores/ha), *Bt kurstaki* (2.0 kg/ha), EPN (*Steinernema carpocapsae* 2 lakh IJ/ha), chlorpyrifos (0.25%) and control replicated thrice in RBD design.

One square meter tobacco nursery beds were raised and when the seedlings were three weeks old, third instar larvae of *S. exigua* were released @ 20 larvae /bed and treatments were applied immediately. Observations were recorded on number of diseased larvae from 24 hours to 7 days after treatment and number of seedlings damaged.

Per cent seedlings damanged by *S. exigua* was lowest in chlorpyrifos (0.25%) treatment which was at par with *N.rileyi* 10^{13} spores/ha and NSKE (2%) and significantly superior to the rest. There were no significant differences among *N. rileyi*, NSKE (2%), *B. bassiana* and *Btk* treatments. EPN was significantly inferior to the rest of the treatments, except control (Table 46). All the treatments were however superior to control without spray. Incidence of disease was maximum in case of *N. rileyi* (12.6) and minimum in case of EPN (3.2).

ii) Validation of trap crop and border crop modules for the management of lepidopteran pests on tobacco (CTRI)

The treatments included were castor as trap crop for *Spodoptera litura* (castor var. DCS-9, Tobacco var. NLS-4) and *Tagetes* as trap crop for *H. armigera* (*Tagetes* var. African marygold, Tobacco var. NLS-4)

Five hectare area at five locations in Krishnampalem village (West Godavari District) was selected. Fifty tobacco plants from each location were sampled and compared with control (without trap crops).

Tobacco with *Tagetes* as trap crop had significantly less damage by *H. armigera* (3.8%) compared to tobacco raised as sole crop (7.0%) wherein there was progressive increase of damage caused by *H. armigera* from 30 to 60 DAT (3.5-18.5) (Table 47).

Table 46. Seedlings damage by *Spodoptera exigua* in tobacco nursery		
Treatment	Mean per cent seedlings damaged (7 DAT)	Cost benefit ratio
Nomuraea rileyi (10^{13} spores/ha)	9.4[ab]	1:27
NSKE (2.0%)	9.7[ab]	1:79
Beauveria bassiana 10^{13} spores/ha	10.2[b]	1:26
Bt kurstaki 2.0 kg/ha	12.5[b]	1:20
EPN (*Steinernema carpocapsae*) 2.0 lakh IJs/ha	18.7[c]	1:16
Chlorpyrifos 0.25%	6.2[a]	1:92
Control	32.5[d]	-

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

Table 47. Efficacy of *Tagetes* as trap crop in tobacco on *Helicoverpa armigera*									
Treatment	Plants damaged by *H. armigera* (%) on day			Larval parasitisation (%) on day					
	30	45	60	Hymenoptera			Diptera		
				30	45	60	30	45	60
Tobacco sole crop	7.0^{b}	9.8^{b}	18.5^{a}	0.8^{a}	3.3^{b}	1.7^{b}	0.0^{a}	2.1^{a}	5.4^{b}
Tobacco + *Tagetes*	3.8^{a}	5.9^{a}	8.4^{b}	2.0^{a}	5.9^{a}	5.0^{a}	0.0^{a}	4.8^{a}	10.7^{a}

Means followed by similar letters are not significantly different (P=0.05) by DMRT; **Apanteles, Campoletis chlorideae*; ** *Carcelia illota, Peribaea orbata.*

Per cent larval parasitisation of *H. armigera* was significantly higher when associated with *Tagetes* as trap crop (5% by hymenopterous and 10.7% by dipterous) than in tobacco grown alone (1.7 and 5.4, respectively) (Table 48). There were no significant differences in canopy temperature and relative humidity when tobacco was grown as sole crop or associated with trap crop.

Damage to tobacco by *S. litura* with castor as trap crop was significantly lower than their counterparts grown without the trap crop (7.5 to 17.3). There was progressive increase in damage caused by *S. litura* in both the treatments from 50 to 70 DAT but the per cent increase was much lesser with trap crop than without trap crop. Larval parasitisation of *S. litura* in tobacco associated with castor trap crop was also significantly higher. Use of trap crop in tobacco increased the yield over control by 44 kg/ha with a cost benefit ratio of 1:2.2.

iii) Studies on the effect of adjuvants in *Sl* NPV persistence and their impact on tobacco quality (CTRI)

Addition of different adjuvants to *Sl* NPV did not provide better control of *S. litura* on tobacco (Table 49). Application of the virus alone at 1.5×10^{12} POB/ha effectively controlled the pest and increased the yield of green and cured leaves.

Table 48. Effect of castor as trap crop in tobacco on *Spodoptera litura*									
Treatment	Damaged plants by *H. armigera* (%) on day			Larval parasitisation (%) on day					
	50	60	70	Hymenoptera			Diptera		
				50	60	70	50	60	70
Tobacco sole crop	7.5^{b}	12.4^{b}	17.3^{b}	4.7^{b}	9.7^{b}	0.3^{a}	1.7^{a}	7.7^{b}	9.7^{b}
Tobacco + *Tagetes*	3.3^{a}	4.8^{a}	7.7^{a}	11.6^{a}	5.9^{a}	3.0^{b}	2.7^{a}	14.7^{a}	22.7^{a}

Means followed by similar letters are not significantly different (P=0.05) by DMRT; * *Chelonus formosanus, Apanteles sp, Charops obtusa;* ** *Peribaea orbata*

Table 49. Effect of adjuvants on the efficacy of *Sl* NPV against *Spodoptera litura* on tobacco				
Treatment	Mean number of larvae / plant	Per cent leaves damaged	Green leaf yield (kg/ha.)	Cured leaf yield (kg/ha.)
Sl NPV 1.5×10^{12} POB/ha. + boric acid 0.025 % + teepol 0.1% + surf 0.1%	4.3^{ab}	3.0^{a}	9353^{a}	2215^{a}
Sl NPV + tannic acid 0.025 % + teepol 0.1% + surf 0.1%	2.3^{a}	4.8^{ab}	7504^{abc}	1498^{abc}
Sl NPV + starch 0.1 % + jaggery 0.1%	10.3^{c}	9.4^{b}	4953^{cd}	1158^{c}
Sl NPV + jaggery0.1% +teepol 0.1%	8.6^{bc}	6.5^{ab}	5654^{bcd}	1254^{bc}
Sl NPV + surf 0.1% + teepol 0.1%	6.6^{b}	3.3^{a}	10161^{a}	1632^{abc}
Sl NPV alone	5.3^{ab}	3.6^{a}	8588^{ab}	2002^{ab}
Control (no spray)	14.0^{d}	16.2^{c}	3954d	784^{c}

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

The cost-benefit ratio was highest when *Sl*NPV was used alone (1:121) followed by *Sl*NPV along with boric acid and teepol (1:99).

3.7. BIOLOGICAL SUPPRESSION OF PULSE CROP PESTS

i) Evaluation of *Bacillus thuringiensis* (DOR *Bt*) against the Pod borers of pigeonpea

TNAU

Laboratory evaluation of DOR *Bt* was carried out on 3rd instar larvae of *H. armigera, Maruca testulalis* and *Exelastes atomosa. Maruca testulalis* was more susceptible than *E. atomosa* and *H. armigera.*

Field evaluation of DOR *Bt* against pigeonpea was done at Puthur village (Coimbatore district) on cv. Co4. Pod damage recorded in NSKE (5%) treatment was 13.9% and in endosulfan (0.07%) it was 14.6% and both were found superior to DOR *Bt* treatment (21.2%) at both the dosages (Table 50).

ANGRAU

DOR *Bt* was evaluated both in laboratory and field against *Helicoverpa armigera* on pigeonpea during *Kharif* 2005-06. In laboratory DOR *Bt* formulation gave 53.2% larval mortality of *H. armigera.*

Field studies indicated that seven days after the administration of treatments, no significant differences were noticed among the treatments with respect to larval population of *H. armigera.* Least number of larvae (8.5/10 plants) was recorded in endosulfan treatment while 12.3 larvae/10 plants were recorded in untreated check, thereby resulting in non-significant differences among the treatments. Similar trends were noticed in the larval populations recorded 7 days after II spray. The damage by *H. armigera* ranged between 16.2 to 18.2 per cent, while pod fly damage was 6.4 to 15.5%. Pod wasp damage ranged from 20.3 to 23.9 per cent thus showing no statistically significant differences among treatments.

Table 50. Field efficacy of DOR *Bt* against pigeonpea pod borer complex

Treatment	Pod damage (%)	Grain yield (kg/ha)
DOR *Bt*. 2kg/ha	21.22^{b}	436.1^{b}
DOR *Bt*. 1kg/ha	23.06^{b}	404.7^{b}
NSKE 5 %	13.94^{a}	511.3^{a}
Endosulfan 0.07%	14.62^{a}	517.2^{a}
Control	21.32^{b}	402.6^{b}

Mean of six replications; Means followed by similar letters are not significantly different (P=0.05) by LSD.

AAU (Anand)

In laboratory tests, DOR *Bt* caused only 22.4% mortality of *H. armigera,* and 20.4% of *M. testulalis.*

ii) Field evaluation of DOR *Bt* against pod borers in pigeonpea (AAU (A))

The treatments comprised of DOR *Bt* @ 2 kg/ha and 1 kg /ha; NSKE @ 5%; endosulfan @ 0.07% compared with control on variety BDN 2.

DOR *Bt* at 2 kg/ha and 1 kg/ha were significantly superior to NSKE (5%) and were at par with other treatments in reducing the population of *M. testulalis* after seven days of spray. Application of endosulfan (0.07%) was significantly better in controlling *M. testulalis* (0.8%). Pod damage and yield data were on par in all three treatments. Similar trend was observed in control of *H. armigera* also (Table 51).

iii) Evaluation of BIPM package on soybean

CTRI

The BIPM package consists of release of egg parasitoids *Telenomus remus* @ 1,00,000 parasitoids/ha for *Spodoptera litura;* one spray of *Sl* NPV @1.5×10^{12} PIB/ha along with 0.5% crude

Table 51. Field evaluation of DOR *Bt* against *Helicoverpa armigera* and *Maruca testulalis*

Treatment	Larvae per plant	
	M. testulalis	*H. armigera*
DOR *Bt* @ 2.0 kg/ha	1.2^{b}	1.4^{b}
DOR *Bt* @ 1.0 kg/ha	1.4^{b}	1.7^{bc}
NSKE (5.0%)	1.6^{b}	2.0^{c}
Endosulfan (0.07%)	0.7^{a}	0.8^{a}
Control	3.8^{c}	4.5^{d}

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

sugar as adjuvant. Chemical control module comprised of one spray of monocrotophos @1.5 ml/l and one spray of chlorypyrifos @ 2.5 ml/l.

There was no significant difference in the number of egg masses of *S .litura* in BIPM and chemical control (0.3 and 0.4/leaf, respectively). Larval population of *S. litura* (per plant) was significantly lower in BIPM plots after one release of *T. remus* @ 1.0 lakh/ha compared to chemical control observed one week after spraying chlorpyrifos (0.25%). There was further significant reduction of *S. litura* larval population after 3 and 7 days of spraying of *Sl* NPV @ 1.5 x 10^{12} PIB/ha. In chemical control the reduction was significantly lesser after second spray of chlorpyrifos (0.25%). There was no infestation of *H. armigera* and pod damage by insects was negligible. Significant difference in yield of soybean in BIPM (1090 kg/ha) and chemical control (950 kg/ha) was observed. BIPM of soybean resulted in Rs.2800/- more net return than chemical control (Table 52).

NRCS, Indore

An IPM Trial was conducted at Indore during *Kharif* 2006 with the treatments: recommended dose of fertilizer; seed treatment with Rhizobium, PSB and *Trichoderma;* soil application of neem cake @500 kg/ha; installation of bird-perches @ 1 per IPM plot; removal of girdle beetle, *Spodoptera* and *Diacrisia obliqua* from infested plants/plant parts; foliar application of *B. bassiana* @ 1.0 kg/ha and need based application of *Triazophos* @ 0.8 kg/ha.

The pest population of the blue beetle, linseed caterpillar, *H. armigera*, tobacco caterpillar, green semilooper, girdle beetle/meter length in IPM plots was lower (1.2, 0.7, 0.3, 2.0, 1.1 and 0.7, respectively) than in non-IPM (4.4, 3.0, 3.1, 6.6, 5.2 and 11.4, respectively).

3.8. BIOLOGICAL SUPPRESSION OF RICE PESTS

i) Evaluation of *Bacillus thuringiensis* (DOR *Bt*) against lepidopteran pests of rice

KAU

Two sprays of DOR *Bt* were given in *Bt* treatments (@1.0, 1.5 and 2.0 kg/ha) and two sprays of quinalphos (0.05%) as insecticidal check were evaluated on var. Jyothi during kharif and rabi seasons.

After second spray, there was no significant difference in leaf folder count between *Bt* (0.2 larva/hill) and chemical control (0.1 larva/hill) and they were significantly superior to control (0.7 larva/hill). All the *Bt* treatments were significantly superior to control in controlling the caterpillar pests like caseworm, horned caterpillar and skipper.

After second spray leaf folder damage was significantly lower in chemical control plots followed by *Bt*-treated plot. Dead heart incidence was significantly lower in chemical control plot followed by all *Bt* treatments (Table 53).

The results of the experiment during rabi season followed a similar trend with reference to leaf folder damage, incidence of other caterpillars, per cent of dead hearts and yield (Table 54 and 55).

Table 52. Evaluation of BIPM package in soybean and cost benefit ratio

Particulars	BIPM	Chemical control
Egg masses of *S. litura*	0.3^a	0.4^a
S. litura larvae population (7 days after release of *T. remus*)	6.5^a	10.3^b
Larval population 3 days after chemical spray	-	4.9
Larval population 7 days after chemical spray	3.0^a	6.0^b
Population of leaf webber before spray	4.7^a	5.3^a
Population of leaf webber 7 days after *Bt* spray	3.1^a	2.0^a
Yield (q/ha)	10.9^a	9.5^b
Cost benefit ratio	1:2	-

Means followed by similar letters are not significantly different (*P*=0.05) by LSD; Cost of soybean Rs20/kg.

Table 53. Population of leaf folder larvae in different treatments								
Treatment	Leaf folder/plant 7 days after second spray				Lepidopterous pests /plant 7 days second after spray			
	No.	Damage (%)	No.	Damage (%)	No.	Damage (%)	No.	Damage (%)
Bt 2.0 kg/ha	0.1[b]	0.3[b]	0.2[b]	4.6[b]	0.3[b]	5.2	0.0[b]	8.1[a]
Bt 1.5 kg/ha	0.1[b]	0.3[b]	0.2[b]	5.9[ab]	0.3[b]	4.3	0.0[b]	7.2[a]
Bt 1.0 kg/ha	0.1[b]	0.2[b]	0.2[b]	3.2[bc]	0.3[b]	5.4	0.0[b]	6.9[a]
Quinalphos (0.05%)	0.0[b]	0.0[b]	0.1[b]	1.6[c]	0.1[b]	3.3	0.0[b]	0.2[b]
Control	0.5[a]	2.5[a]	0.7[a]	8.2[a]	0.7[a]	7.3	0.4[a]	8.5[a]

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

Table 54. Population of leaf folder larvae in different treatments								
Treatment	Leaf folder/plant 7 days after second spray				Lepidopterous pests /plant 7 days second after spray			
	No.	Damage (%)	No.	Damage (%)	No.	Damage (%)	No.	Damage (%)
Bt 2.0 kg/ha	0.2	2.7[b]	0.1[b]	2.0	0.1[b]	12.8[a]	0.1[b]	9.2
Bt 1.5 kg/ha	0.3	3.2[b]	0.2[b]	1.8	0.03[b]	14.3[a]	0.1[b]	8.3
Bt 1.0 kg/ha	0.2	1.8[b]	0.2[b]	1.9	0.03[b]	12.4[a]	0.1[b]	10.0
Quinalphos (0.05%)	0.3	0.4[c]	0.1[b]	1.6	0.03[b]	4.4[b]	0.0[b]	4.5
Control	0.5	7.2[a]	0.5[a]	2.3	0.5[a]	15.7[a]	0.6[a]	8.9

Means followed by similar letters are not significantly different (P=0.05) by DMRT; Data were transformed ($\sqrt{x+0.5}$) before analysis

Table 55. Pest damage, yield and cost benefit ratio in Kharif and rabi seasons						
Treatment	White earheads (%)		Gain yield (kg/ha)		Cost benefit ratio A/B	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
B. t. 2 kg/ha	1.2[ab]	5.8	3195.0	4382.5[a]	8.29	2.08
*B. t.*1.5 kg/ha	1.2[ab]	4.8	3257.5	4575.0[a]	6.65	1.70
B. t. 1kg/ha	1.4[ab]	4.8	3257.5	4100.0[ab]	45.8	3.04
Quinalphos (0.05%)	0.6[b]	5.3	2735.0	3745.0[bc]		7.43
Control	2.0[a]	6.2	2972.5	3497.5[c]		

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

AAU (Jorhat)

The experiment was conducted in the farmer's field located at Bekajan, Jorhat, Assam on the variety 'Ranjit'. The treatments imposed were DOR *Bt* 2.0, 1.5 and 1.0 kg/ha, spray of chlorpyriphos as check and control.

Irrespective of the dose DOR *Bt* could reduce the dead heart incidence significantly (2.7-3.2%) and was at par with the insecticidal application (3.1%). The incidence of white earhead was also reduced due to DOR *Bt* application (2.8-4.1%). DOR *Bt* also had significant effect in reducing the larval population of leaf folder and case worm after 5 and 7 days of each treatment. DOR *Bt* 2.0 kg/ha gave the highest yield of 3860.8 kg/ha as against 2923 kg/ha in the control plot. However, DOR *Bt* (1.5 kg/ha) and DOR *Bt* (1 kg/ha) were at par with the insecticidal treatment (3626 kg/ha). in respect of yield.

PAU

The experiment on DOR *Bt* against leaf folder and stem borer of rice was conducted at farmer's field at village Karni Khera (Distt. Ferozepur). The incidence of leaf folder at 60 DAT was significantly reduced in *Bt* @ 2.0 kg/ha (2.4%) and monocrotophos 36SL (2.0%), whereas medium dose of *Bt* @ 1.5 kg/ha (4.2%) and lower dose of *Bt* @ 1.0 kg/ha (4.5%) were at par with control (4.6%). In all the treatments the per cent dead hearts at 45 and 60 DAT were significantly lower than in control (12.4% and 2.7%). The per cent white ear incidence was lowest in *Bt* @ 2kg/ha (0.6%) and all other treatments were at par with the higher dose of *Bt* except for the control (3.1%). The highest yield was recorded in monocrotophos 36SL (67.1 q/ha) followed by *Bt* @ 2.0kg/ha (66.4 q/ha) and yield in all the treatments was higher than in control (52.3q/ha).

ii) Evaluation of DOR *Bt* against Leaf Folder and Stem Borer of *Basmati* Rice (PAU)

The experiment was conducted at farmer's field at village Karni Khera (Distt. Ferozepur). All the treatments were significantly better than control with respect to leaf folder damage (5.7%) at 60 DAT. The higher dose of *Bt* @ 2.0kg/ha (1.8%) was at par with standard chemical check, Padan 4G (1.7%) where as medium dose (3.0%) and lower dose (3.2%) were significantly lower than standard chemical check at 60 DAT. The per cent dead hearts at 45 and 60 DAT in all the treatments were significantly lower than control (8.1% and 5.7%). The per cent white ears in all the treatments were significantly lower than control (10.1%) except for lower dose of *Bt* (9.3%) which was at par with control. The highest yield was recorded in Padan 4G (23.2 q/ha) followed by higher dose of *Bt* (22.3 q/ha) and yield in all the treatments were however significantly better than control (16.8 q/ha) (Table 56).

It can be concluded that higher dose of *Bt* @ 2.0kg/ha was at par with Padan 4G and it proved to be effective for the management of rice leaf folder and stem borer on *Basmati* rice.

iii) Validation of biointensive pest management practices in organic rice production

PAU

BIPM practices in organic rice production were validated on *Basmati* rice and coarse rice (var. PR 116). In the organic farming, green manuring was done with *Dhaincha*; *Trichogramma chilonis* and *T. japonicum* were released each @1,00,000/ha/week, 7 times starting 30DAT. In the conventional recommended practices, nutritional requirement was met with inorganic recommended fertilizers and one spray of monocrotophos @1.4 l/ha. In the integrated practices, half of the nutritional requirement was met with inorganic fertilizers and other half with organic fertilizers and parasitoids were released as in organic farming treatment.

The incidence of the leaf folder at 60 DAT was lower in recommended practices and incidence of stem borer was lower in integrated practices. The per cent white ears was lowest in integrated practices (Table 57). The yield in the integrated practices (35.70 q/ha) and to recommended practices (35.60 q/ha) were higher than in organic practices (31.20 q/ha). In the experiment with PR 116, leaf folder damage and dead hearts were minimum in organic practices. Howerver, lowest per cent white ears and highest yield were recorded in recommended practices.

Table 56. Evaluation of DOR *Bt* against leaf folder and stem borer in *Basmati* Rice

Treatment	Leaf folder damage (%) at 60 DAT	Dead hearts (%) at 60 DAT	White ears (%)	Yield (q/ha)
Bt @ 2.0kg/ha	1.8[a]	1.7[a]	3.2[b]	22.3[a]
Bt @ 1.5kg/ha	3.0[b]	3.6[b]	6.5[c]	20.9[b]
Bt @ 1.0kg/ha	3.2[b]	3.9[b]	9.3[d]	18.1[c]
Padan 4G	1.7[a]	1.4[a]	2.1[a]	23.2[a]
Untreated Control	5.7[c]	5.7[c]	10.1[d]	16.8[d]

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

Table 57. Validation of BIPM practices in different rice varieties

Treatment	Leaf folder damage (%) at 60 DAT		Dead hearts (%) at 60 DAT		White ears (%) at harvest		Yield (q/ha)	
	Basmati	PR 116	*Basmati*	PR 116	*Basmati*	PR 116	*Basmati*	PR 116
Organic practices	3.6^{c}	0.2^{a}	8.1^{b}	1.2^{a}	5.1^{c}	4.4^{b}	31.2^{b}	46.6^{c}
Recommended practices	2.6^{a}	3.2^{c}	9.8^{c}	6.3^{c}	3.2^{b}	1.9^{a}	35.6^{a}	60.8^{a}
Integrated practices	3.4^{b}	0.3^{b}	6.7^{a}	2.1^{b}	2.4^{a}	2.3^{a}	35.7^{a}	54.3^{b}

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

KAU

The experiment was carried out on var. Jyothi with the following practices: Application of farmyard manure @ 5 t/ha, seed treatment with *Pseudomonas* @ 8 g/kg, erection of bird perches @ 10 nos./ha and four releases of *T. japonicum*.

There was no significant differences between the treatment in pest damage due to leaf folder, plant hopper and rice bug. In the case of stem borer, a significantly higher dead heart symptom was recorded in conventional farming while white ear head occurrence was on par in both cases. Grain yield in conventional (4478.7 kg/ha) was on par with organic farming (4449.3 kg/ha). Significantly higher population of natural enemies like spiders and coccinellids was found in organic farming than in conventional farming. The cost benefit ratio in organic practice was 8.5 considering the cost of increased yield/ha @ Rs.10/kg.

iv) Validation of BIPM practices against pest complex in rice (KAU)

The trial was laid out in 4 ha area in Kanimangalam on var. Jyothi to evaluate BIPM with farmer's practice. In BIPM *Pseudomonas fluorescence* was used for seed treatment. Dewatering the field and neem oil spray was given for case worm management. Four releases of *T. japonicum* @ 1 lakh/ha were made at fortnightly intervals. There was no significant difference in grain yield between the two areas (7594 and 7169 kg/ha, respectively). Spider and coccinellid population was significantly higher in BIPM area (2-3/plant).

v) Demonstration of biocontrol based IPM on *Basmati* Rice (PAU)

BIPM was demonstrated on 10 ha plot at village 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/week, starting 30 DAT. In chemical control, three applications of cartap hydrochloride (Padan 4G) were given @ 25kg/ha, 30, 50 and 70 DAT.

The lowest incidence of leaf folder was recorded on 45 DAT in BIPM, which was at par with chemical control. The dead hearts in chemical control was significantly lower than BIPM and control at 60 DAT. The yield in IPM (22.7 q/ha) and chemical control (23.2 q/ha) were significantly higher than in control (16.6 q/ha) (Table 58). The per cent parasitism of *Corcyra* eggs and natural parasitism in IPM (12.1% and 9.5%) were significantly higher than chemical control (2.3% and 2.1%) and control (1.8% and 1.2%). BIPM module was observed to be as effective as chemical control for the management of rice pests.

Table 58. Evaluation of BIPM practices in *Basmati* rice

Treatment	Leaf folder damage (%)	Dead hearts (%)	White ears (%)	Yield(q/ha)	Cost benefit ratio
BIPM	2.2^{b}	2.3^{b}	4.2^{b}	22.7^{b}	1:2.3
Chemical control	1.5^{a}	1.5^{a}	3.4^{a}	23.2^{a}	1:3.3
Control	4.6^{c}	5.2^{c}	10.9^{c}	16.6^{c}	

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

3.9 BIOLOGICAL SUPPRESSION OF OILSEED CROP PESTS

i) Evaluation of natural enemies of mustard saw fly for use in biocontrol

AAU (Anand)

No parasitoids or pathogens could be recorded from the field-collected larvae of the mustard saw fly. The larvae were predated by the common myna, *Acridotheres tristis* in the late evening.

Laboratory screening of sawfly for susceptibility to Biolep & DOR *Bt* (@ 0.75, 1.0 and 1.25 g/l, *Beauveria bassiana* (@ 10^9, 10^{10} and 10^{11} conidia) and *Metarhizium anisopliae* (@ 10^9, 10^{10} and 10^{11} conidia) was carried out to work out the LC_{50}.

The mortality data showed that neither the *Bt* nor the fungal pathogens were able to give appreciable mortality of the saw fly larvae (Table 59).

Table 59. Laboratory screening for the susceptibility of mustard sawfly

Treatment	Dosage	Per cent mortality after 120 hr
Bt (Biolep) (g/l)	0.75	17.5^{c}
	1.0	20.8^{b}
	1.25	24.0^{a}
DOR *Bt* (g/l)	0.75	23,8^{b}
	1.0	28.0^{a}
	1.25	29.5^{a}
B. bassiana (conidia/l)	10^9	8.3^{b}
	10^{10}	9.5^{ab}
	10^{11}	10.8^{a}
M. anisopliae (conidia/l)	10^9	7.8^{b}
	10^{10}	8.8^{b}
	10^{11}	10.5^{a}

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

ii) Field evaluation of *Bt* and fungal pathogens (AAU (J))

An experiment was conducted at ICR farm on mustard variety M-27 on biocontrol of mustard saw fly.

At 10 DAS, the incidence of mustard sawfly was minimum in the plots treated with *Beauveria bassiana* (1x10^{13} conidia/ha), and DOR *Bt* (2.0 kg/ha) (2.3 larvae/10plants), followed by *Metarrhizium anisopliae* (1x10^3 conidia/ha) (2.7). These treatments were at par with each other. The lowest per cent damaged leaves was observed in insecticide treated plots (2.4%). The yield in insecticide plot (602.5 kg/ha) was at par with DOR *Bt* (2.0 kg/ha) (563.5 kg/ha).

3.10. BIOLOGICAL SUPPRESSION OF COCONUT PESTS

i) Evaluation of *Trichogramma embryophagum*, *Goniozus nephantidis* & *Cardiastethus exiguus* against *Opisina arenosella* (KAU)

Sequential releases of *T. embryophagum* @ 1000/palm, *C. exiguus* numphs @ 50/palm and *G. nephantidis* adults @ 10/palm at Vatanapilly area in Thrissur district resulted in negligible population of *Opisina arenosella* (Table 60).

Table 60. Counts of *Opisina arenosella* /leaflet

Treatment	Pre released count	Post release count
T. embryophagum adults @ 1000/palm	0.5	0.04^{ab}
C. exiguus numphs @ 50/palm	0.6	0.0^{b}
G. nephantidis adults @ 10/palm	0.5	0.1^{a}
Sequential release of *T. embryophagum* & *G. nephantidis*	0.5	0.0^{ab}
Sequential release of *C. exiguus* & *G. nephantidis*	0.5	0.0^{ab}
Control (no release of parasitoids)	0.4	0.1^{a}

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

ii) Validation of biological suppression of coconut rhinoceros beetle *Oryctes rhinoceros* using *Oryctes baculovirus* and *Metarrhizium anisopliae* in homestead gardens (KAU)

The experiment was carried out in one-hectare area at College of Horticulture, Vellanikkara. Adult Rhinoceros beetles were collected by keeping Rhinolure in farmers' fields. Released OBV treated adults @ 10 adults/ha in the evening hours after 24 hours starvation. Population build-up could not be noticed on 30 and 45 days after release.

Collected the nucleus culture of *Metarhizium anisopliae* from CPCRI Kayamkulam and mass cultured in coconut water. Twenty-five days after inoculation collected the fungal materials and applied in the breeding media @ 10 bottles/m^2 area. Recorded pre counts and post counts of grubs and pupae. The post counts indicated 100% infection of the population.

3.11. BIOLOGICAL SUPPRESSION OF TROPICAL FRUIT CROP PESTS

i) Population dynamics of soft green scale *Coccus viridis* and its natural enemies on sapota (IIHR)

The study was conducted on eight-year-old sapota plants (var. Cricket ball). The population of green scales ranged from 1.10/leaf in December to 11.84/leaf in July 2005. 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 60.24% in April 2005 to 93.40% in October 05. *C. nigrita* was observed in negligible numbers during August to December 05. The population of the scale was very low in October to December mainly due to the activity of *Coccophagus* sp.

ii) Evaluation of *Verticillium lecanii* against sapota green scale *Coccus viridis* (IIHR)

Sapota twigs infested with the green scales were sprayed with the fungus *V. lecanii* @1x 10^7, 1x 10^8 to 1x10^9 along with 2 per cent sunflower oil. A control (scales exposed to a thin film of distilled water) and a check treatment. Scales exposed to Rogor (2ml/l) were also run parallel to other treatments.

A dose of 10^9 spores/ml produced a mortality of 8.8 per cent. When the twigs sprayed with the fugal suspension were covered with a cloth bug, the mortality increased to 29.5%, probably due to enhanced humidity.

iii) Laboratory evaluation of *Verticillium lecanii* against Mango hopper, *Ideoscopus nitidulus* (IIHR)

Three different spore concentrations of *V. lecanii* viz., 1.0 x 10^9, 1.0 x 10^8 and 1.0 x 10^7 spores/ml were evaluated in the laboratory against the mango hoppers, *I. nitidulus*. A control treatment where the hoppers were exposed to a fine spray of distilled water was also run parallel to the other treatments.

Results showed that all the three concentrations of the fungus were effective in inflicting 69.5 to 92.0% mortality of the hoppers at 72 hours of incubation. A maximum of 92.0% mortality was recorded at 1.0 x 10^9 followed by 87.9% in 1.0 x 10^8 and 69.5% in 1.0 x 10^7 spores/ml, respectively.

iv) Biology of *Isyndus heros*, a predator of mango hoppers (IIHR)

The predator was maintained on the larvae of rice moth *Corcyra cephalonica* in the laboratory. Egg period was 12 days. There were 5 nymphal instars. Duration of I, II, III, IV and V instars was 9,14,7,10,18 days, respectively. It took 55 days to complete the life cycle.

v) Field evaluation of natural enemies against mango hoppers (IIHR)

Field evaluation of the entomopathogen *M anisopliae* and *Verticillium lecanii* was carried out against *I. nitidulus* infesting mango var. Alponso. The fungii were multiplied in the laboratory on sorghum. Three different spore concentrations of *M. anisopliae* and *V. lecanii* @ 1x10^9 spores/ml along with the check (Imidachlorpid 0.25ml/l) and control (distilled water) were evaluated.

Application of *M. anisopliae* caused about

67.0 per cent mortality of mango hoppers followed by 58.9% recorded in *V. lecanii* treatment. The per cent mortality in both the fungal treatments was significantly higher than in control. Spraying of the chemical recorded maximum mortality of 92.0 per cent that was statistically superior to the fungal treatments.

vi) Effect of off-season release of *Cryptolaemus montrouzieri* to suppress the mealybug on custard apple during the main season (IIHR)

To study the off-season release effect, a custard apple orchard of 0.75 acres containing 100 plants was chosen at IIHR Farm. The mealybugs. *Planococcus citri* and *Maconellicoccus hirsutus* appeared in severe form during August- September. The predators released during November to January. Mealy bugs were not observed from January to April. In May, the mealybugs started appearing on the just formed fruits and only 3% plants were found infested with the mealy bugs in May. A mean 36.98% reduction in the plant infestation and 18.9% reduction in fruit infestation was observed in October due to the release of the predator.

vii) Safety of newer pesticide to *Cryptolaemus montrouzieri* (IIHR)

A total of 15 new molecules were tested for their safety to the larvae of *C. montrouzieri* Both the initial toxicity on the day of application and residual toxicity at different days after application were studied. Among them, abamectin 0.5ml/l, fipronil1.5ml/l, novaluron 0.75ml/l, fluvalinate0.5ml/l,b profenophos 1ml/ and flufenoxuron 1ml/l did not cause any mortality. Polytrine, imidacloprid and ethofenprox proved to be relatively less toxic one day after application. Biofenthrin (Talstar) and thiodicarb (Larvin) had adverse effects on the predator even beyond 35[th] day of application.

viii) Effect of commonly used pesticides in the flowering stage on the reduviid predator *Isyndus heros* (IIHR)

A total of 12 insecticides commonly used in mango ecosystem were screened for their safety to the mango hopper predator *I. heros*. Among them, fenvalerate, monocrotophos, acephate, fipronil, iamdocyalothrin and fluvalinate did not cause any mortality of the predator. Imidocloprid, carbaryl and polytrin proved to be harmless one day after application while other chemicals were non-toxic only on 14[th] day of application.

ix) Efficacy of the aphelinid parasitoid *Encarsia guadeloupae* in the suppression of spiraling whitefly under glass house condition (IIHR)

Heavy incidence of spiralling whitefly was observed on guava plants in the glass house in February 2005. *Encarsia guadeloupae* were released on the infested plants. The spiraling whitefly was brought under control in October 2005. Parasitism by *E. guadeloupae* went up to 86.70%. The population declined from120.35/leaf in February 2005 to 2.12/leaf in October 2005. The temperature ranged from 21 to 40°C and the humidity ranged from 51 to 91% in the glass house.

x) Studies on the natural enemies of thrips on pomegranate, mango and grapes (IIHR)

No parasitoid/predator was collected on *Scirtothrips dorsalis* attacking pomegranate and grapes. However, the fungus *V. lecanii* was found to be pathogenic to both pomegranate and grape thrips in the laboratory.

xi) Impact of naturally occurring predators in the suppression of amla aphid, *Schoutedenia emblica* (IIHR)

Heavy incidence of the aphid *Schoutedenia emblica* was observed on amla in March 2005 (2700 aphids/shoot of 15 cm length).. The coccinellid predator *Cheilomenes sexmaculata* appeared in the first week of April. By the end of April, the population declined to 1558/pant. The plants were completely cleared of aphids in the last week of May 2006. A mean of 18 larvae of *C. sexmaculata* were observed per shoot of 15 cm length in April.

xii) Demonstration on the performance of bioagents (IIHR)

A) *Encarsia guadeloupae* in the suppression of guava spiralling whitefly

A demonstration was conducted on guava (three-year-old plants) var. *Allahabad Safeda* infested with spiralling whitefly at Tarahunsae village, Bangalore North (A total of 424 adult parasitoids of *E. guadeloupae* were released during August 2005). Prior to the release, there was no activity of *Encarsia*. Release of *E. guadeloupae* were initiated on 25th August 05 and continued up to 14th March 06. The parasitoid was recovered in two months after the first release, and 29.2% parasitism was recorded. The population of the spiraling whitefly declined gradually from 128.20/ leaf in August 05 to nil in March 05 in the parasitoid-released orchard as compared to 70.8 whiteflies/ leaf in the control guava orchard. There was no parasitoid activity in the check orchards. Parasitism by *E. guadeloupae* started increasing steadily in the treated orchard after the first recovery (Table 61) and reached up to 100% in March 2006. Spiralling whitefly population was brought down mainly due to the activity of *E. guadeloupae*.

B. *Cryptolaemus montrouzieri* in the suppression of green shield scale on guava

Severe infestation of green shield scale was observed in July 2006 in the guava orchard located at Kakol village Bangalore North. The predator *C. montrouzieri* started appearing by the end of June 2005 and 15-20 larvae of *C. montrouzieri*/plant were observed feeding on the scales. The population of scales declined from 46.84 /plant in June to 1.52/ plant in August 2006 mainly due to the predation by *C. montrouzieri*.

3.12. BIOLOGICAL SUPPRESSION OF TEMPERATE FRUIT CROP PESTS

i) Development of biointensive IPM for San Jose Scale, *Quadraspidiotus perniciosus* in apple ecosystem (SKUAS&T)

A study was conducted in three isolated orchards, one was IPM managed with approximately 80 apple trees, where 1.5% oil spray (ATSO) was applied to 50 labeled trees and laboratory reared *Encarsia perniciosi* were released on 20 randomly selected trees @ 1000 individuals/tree. Another was a Government orchard that received state government recommended chemical schedule and a third untreated check (50-60 scattered apple trees) which received no treatment.

Per cent parasitism ranged from 4.76 to 23.59 in IPM orchard, 2.96 to 8.92 in government orchard and 5.86 to 16.02 in control, indicating a positive impact of augmentative releases (Table 62). Chemically managed orchard, however, yielded a very low level of scale parasitism without any definite pattern. Coefficient of correlation (r^2) between per cent parasitism and scale infestation revealed a statistically negative correlation in the managed orchard (Table 63).

Table 61. Efficacy of *Encarsia guadeloupae* against spiralling whitefly on guava

Date	Number of *E. guadeloupae* released	Population of whiteflies/leaf		Parasitism (%)
		Released plot	Check	
25-08-2006	80	128.20	110.84	0.00
24-10-2006	260	73.00	83.12	29.20
16-12-2004	--	53.60	64.71	40.29
13-01-2005	--	16.80	56.00	78.64
17-02-2005	--	3.10	40.89	90.15
12-03-2005	--	0.00	70.80	100.00

Table 62. Comparative observations on San Jose scale infestation and parasitisation						
Months	Managed orchard (T_1)		Unmanaged orchard (T_2)		Chemically managed orchard (T_3)	
	Number of scales /2 cm^2	Parasitism (%)	Number of scales /2 cm^2	Parasitism (%)	Number of scales /2 cm^2	Parasitism (%)
March	8.06	4.76	15.08	5.86	10.9	2.96
April	10.36	6.28	20.0	7.35	13.88	4.49
May	14.81	10.95	26.6	10.53	11.8	5.94
June	47.04	16.71	47.18	12.42	14.8	6.97
July	51.3	18.9	53.46	16.02	12.88	7.85
August	51.43	23.59	64.9	15.47	15.61	6.49
September	39.93	21.9	37.21	10.94	20.35	8.92

Each figure in columns represents mean of 20 observations, replicated three times.

Table 63. Coefficient of correlation (r^2) between parasitism and scale infestation in managed and unmanaged orchards				
Months	Managed orchard		Unmanaged orchard	
May	-0.22	NS	-0.54	Sig.*
June	-0.37	NS	-0.41	NS
July	-0.49	Sig.*	-0.19	NS
August	-0.51	Sig.*	-0.06	NS
September	-0.50	Sig.*	-0.21	NS

ii) Evaluation of fungal pathogens against wooly aphids (Dr.YSPUH & F)

Trees infested with woolly apple aphid colonies were sprayed with *B. bassiana*, *M. anisopliae* and *V. lecanii* at 10^7 conidia/ml (10^{13} conidia/ha) in December 2005. The mean pre-treatment aphid colony size varied non-significantly from 0.43 to 0.68 cm and 10-days after treatment, per cent reduction in colony size was 22.3, 30.6, 28.9 and 37.5 in the three treatments and control, respectively, while after second spray, the reduction was 46.6, 40.3, 49.4 and 47.8 per cent, respectively, which indicated no impact of the fungi on the aphids.

iii) Study on the fungus isolated from the defoliating beetle, *Brahmina coriacea* (Dr. YSPUH & F)

Three exotic isolates of *B. brongniartii*, a local isolate of *B. brongniartii*, and *B. bassiana* and *M. anisopliae* procured from PDBC, Bangalore, were tested against second and third instar grubs by dip treatment. Best results were obtained with B. brongniartii (local strain) at 10^7 and 10^8 conidia resulting in 70 and 76.7% kill of II-instar and 63.3 and 66.7% kill of III-instar grubs after 7 weeks of the treatment, and both these concentrations were equally effective. B. bassiana provided 63.3 and 66.7% kill of II-instar and 56.7 and 60% kill of III-instar grubs. Other three strains of B. brongniartii were less effective, giving 43.4-56.7% mortality of II- and III- instar grubs at 10^8 conidia/ml concentration and M. anisopliae was least effective (26.7 and 16.7% kill of II- and III-instar larvae at 10^8).

3.13. BIOLOGICAL SUPPRESSION OF VEGETABLE CROP PESTS

i) Biological control of DBM on cabbage (IIHR)

The efficacy of DOR *Bt* (1.0 g/l), *B. bassiana* (15 g/l) and EPN (1 billion/ha) Dipel (1 ml/l) were compared with endosulfan (2 ml/l).

A mean larval population of 16.1, 11.7, 12.6 and 7.4 /plant was recorded in the plots sprayed with DOR *Bt* , *B. bassiana*, *S. carpocapsae* and Dipel, respectively. The chemical treatment recorded a mean larval population of 9.7 larvae per plant, while control plot recorded 24.2 larvae per plant. There was a significant difference in yield between various treatments (26.5 to 29 t/ha). Dipel recorded the maximum yield (29 t/ha) and in control the yield was 13 t/ha (Table 64).

Table 64. Effect of biological control agents on the incidence of *Plutella xylostella*			
Treatment	Pre-treatment count	Mean population	Yield (t/ha)
DOR *Bt*	6.5	16.1[d]	24.4[b]
Beauveria bassiania	6.5	11.7[bc]	28.7[a]
EPN	6.3	12.6[c]	28.0[a]
Bt formulation (Dipel)	6.0	7.4[a]	29.0[a]
Endosulfan	6.7	9.7[ab]	26.5[a]
Control	6.7	24.2[e]	13.0[c]

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

ii) Evaluation of EPN against brinjal shoot and fruit borer

IIHR

EPN was evaluated on the brinjal var. Arka Neelakanth in an area of 500 m^2 with five treatments. Three dosages of the nematodes *S. carpocapsae* @1, 1.5 and 2 billion/ha were compared with the standard check (Cypermethrin 25 %E C - 0.5 ml/l) and control. First spray at the above-specified concentrations was imposed following initiation of about five per cent flowering. Ten sprays were applied at weekly interval during the evening hours. The field was irrigated before the day of spraying.

The per cent infestation at harvest in control plots varied from 13.8 to 40.76 with a mean of 14.4 per cent fruit damage. In EPN treatments there was significant reduction with the infestation varied from 4.4 to 18.1 per cent, and a mean fruit damage of 7.9, 7.8 and 7.8 in *S. carpocapsae* sprayed @ 1. 1.5 and 2 billion /ha, respectively. A mean of 8.9 per cent damage was recorded in the cypermethrin treated plot, which was superior to control. The yield was higher in EPN @ 2.0 billion/ha (32.5 t/ ha) treatment, which was as effective as chemical control (31.1 t/ha).

KAU

The experiment was conducted using var, Swetha. The pest incidence was significantly lower in chemical control plot than in biocontrol treatments.

The overall mean fruit infestation was lowest in *Bt* applied at 2.0 kg/ha (13.6%), which was on par with EPN (17.4%) and chemical control treatments (19%). Untreated control recorded significantly higher shoot and fruit infestation. Fruit yield was highest in EPN and on par with *Bt* and quinalphos treated plots, followed by *T. chilonis* released plots (Table 65).

iii) Microbial control of *Trialeurodes vaporariorum* using fungal pathogen (Dr.YSPUH & F.)

On potted and whitefly infested bean plants, conidial suspensions of *Beauveria bassiana*, *Verticillium lecanii* and *Fusarium pallidoroseum* were sprayed at 10^7, 10^8 and 10^9 conidia/ml. While *V. lecanii* @ 10^9 conidia/ml provided 88.0% nymphal mortality in 15 day observation, it was 82.3% in the case of *B. bassiana*. With *F. pallidoroseum*, mortality was comparatively lower (56.6%). Under glasshouse conditions, *V. lecanii* at 10^8 and 10^9 conidia/ml spore suspension, provided only 32.0 and 43.3% kill and *B. bassiana*, 19.3 and 27.7% after 15 days of treatment. *Fusarium pallidoroseum* was not effective.

iv) Evaluation of DOR *Bt* against fruit borers of brinjal and okra

KAU

Four *Bt* sprays were applied at three concentrations (1.0, 1.5 and 2.0 kg/ha) on okra var. Salkeerthy and for comparison malathion (0.05%)

Table 65. Biological control of shoot and fruit borer in brinjal		
Treatment	Shoot infestation (%)	Fruit yield (kg/ha)
EPN @ 1b/ha	18.2[ab]	5957.5[a]
EPN @ 2b/ha	17.4[ab]	5721.5[a]
Bt @ 2.0 kg/ha	13.6[a]	5272.6[a]
T. chilonis @ 50000/ha	21.0[bc]	4237.3[b]
Chemical control	19.0[ab]	5349.8[a]
Control	25.2[c]	3615.4[b]

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

was used. There was no significant difference between the treatments with respect to shoot damage (26.8-38.4%). Significantly low fruit infestation was recorded in chemical control (1.7%). There was no significant difference between fruit yield and treatments (1208 to 1241 kg/ha) (Table 65). These results indicate that application of *Bt* @ 1.0kg/ha was as effective as spraying 0.05% malathion (Table 66).

In another experiment on brijal, four *Bt* sprays were given @ 1.0, 1.5, 2.0 kg/ha on var. Haritha. Malathion (0.05%) spray was used as a standard check. The overall mean fruit infestation was minimum in *Bt* 2.0 kg/ha (21.7%) and maximum in control plot (50.4%). Fruit yield was maximum in *Bt* 2.0 kg/ha (5290 kg/ha). All other treatments were on par (2448 to 3041 kg/ha). The cost benefit ratio was high in *Bt* (1.0 kg/ha) considering the cost of increased yield/ha over control (Table 67).

PAU

The experiment on evaluation of DOR *Bt* against fruit borer, *Earias* spp. on okra was conducted using var. Punjab 8 with five treatments, *viz.* DOR-*Bt* (1.0, 1.5 and 2.0kg/ha) and endosulfan (350ml/acre) as standard check and a control plot.

All the treatments except DOR *Bt* (1.0kg/ha) showed lower damage than control (Table 68). The fruit damage was lowest in endosulfan and it was at par with higher dose (2.0kg/ha) of DOR *Bt* (28.3%). The highest yield (90.3 q/ha) was obtained from the plots treated with endosulfan and it was at par with higher dose (2.0 kg/ha) of DOR *Bt*. It can be concluded that DOR *Bt* @2.0kg/ha was at par with chemical control and it proved effective for the management of *Earias* sp. on Okra.

Table 66. Biological control of shoot and fruit borer in okra

Treatment	Shoot infestation (%)	Fruit infestation after 4 sprays	Total yield (kg/ha)
Bt @ 2.0 kg/ha	26.8	4.6 ab	1241.3
Bt @ 1.5 kg/ha	28.9	3.2 ab	1208.8
Bt @ 1 kg/ha	26.9	6.7 a	1223.0
Chemical control	38.4	1.7 b	1236.8
Control	31.2	5.9 ab	1155.3

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

Table 67. Efficacy of *Bt* against shoot and fruit borer in brinjal

Treatment	Shoot infestation (%)	Fruit infestation after 4 sprays	Total yield (kg/ha)
Bt @ 2.0 kg/ha	26.8	21.7a	5290a
Bt @ 1.5 kg/ha	28.9	33.2b	3041b
Bt @ 1 kg/ha	26.9	38.6b	2537b
Chemical control	38.4	33.7b	2775b
Control	31.2	50.4b	2448b

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

Table 68. Evaluation of *Bacillus thuringiensis* formulation against fruit borer on Okra

Treatment	Per cent fruit damage	Fruit yield (q/ha)
DOR- Bt5 (2.0kg/ha)	28.3a	79.6a
DOR- Bt5 (1.5kg/ha)	34.2a	73.1b
DOR- Bt5 (1.0kg/ha)	42.3b	64.9b
Endosulfan (350ml/acre)	28.0a	90.3a
Control	44.4b	55.3c

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

v) Effectiveness of various microbial pesticides and a summer oil against *Pieris brassicae* (Lepidoptera:Pieridae)

A. Knol khol (SKUAS & T)

Various microbial pesticides, *viz.*, *Beauveria bassiana* @ 1×10^{13} spores/ha, *Bacillus thuringiensis* @ 1.0 kg/ha, *Metarhizium anisopliae* @ 10^{13} conidia/ha, *Heterorhabditis indica* @ 2 billion/ha, a summer oil (DC Tron Plus @ 0.75%), neem (1.0%) and dichlorvos (0.05%)

were evaluated for their efficacy against *Pieris brasicae* on knol-khol under field conditions and compared with an untreated check. On 2nd day dichlorvos recorded 45% mortality, which increased to 100% on 8th day. Among microbials, *B. bassiana* recorded initial mortality of 9.3% on 2nd day, which reached to 72.3% followed by *M. anisopliae* recording 51.7% mortality. *Bacillus thuringiensis* and neem could only record 47.3 and 47.7% mortality, respectively, up to 16th day. DC Tron Plus recorded 63.7% mortality, but phytotoxicity was observed on its application. *Heterorhabditis indica* was least effective recording only 10.7% mortality (Table 69).

B. Cauliflower (Dr. YSPUH & F)

Bacillus thuringiensis kurstaki (Btk) (1.0 kg/ha), *Beauveria bassiana* (10^{11} conidia/l), Eco Neem Plus (0.2%), summer spray oil (DC Tron Plus, 0.75%), and dichlorvos (0.05%) were applied on cauliflower for suppression of cabbage butterfly larvae.

Results indicated that after 10 days of the treatment, there was no live larva on plants treated with neem and dichlorvos. However, on Btk treated plants, 5.7 larvae /plant were recorded. The per cent damaged leaves in various treatments did not differ significantly but the graded leaf damage was significantly low on plants treated with Btk (0.21%), neem (0.21%) and dichlorvos (0.20%), other treatments being ineffective (Table 70).

vi) Evaluation of some fungal bio-control agents for the control of cabbage aphid (*Brevicoryne brassicae*)

Dr. YSPUH & F

Three fungal preparations, *viz. Verticillium lecanii, Beauveria bassiana* and *Fusarium pallidoroseum*, each at 10^{11} conidia/l water, summer spray oil (DC-Tron Plus 0.75%) and oxydemeton methyl (0.025%) were evaluated on cabbage aphid and among them none proved effective except oxy demeton methyl.

SKUAS&T

Among the microbials, *V. lecanii* @ 10^{13} conidia/ha caused initial mortality of 34.3%, which increased to 75% on 12th day. *Beauveria bassiana*

Table 69. Biological control of *Pieris brassicae* larvae on knol khol

Treatment	Per cent mean mortality (Days after application)		
	2	8	16
Beauveria bassiana @ $1x10^8$ spore/ml	9.3	18.0	72.3
Bacillus thuringiensis @ 1.0 kg/ha	0.0	10.3	47.3
Metarhizium anisopliae anisopliae @ $1x10^{13}$ spore/ml	2.0	22.2	51.7
Heterorhabditis indica @ 2 billion /ha	0.0	0.0	10.7
D.C.Tron Plus (0.75)	12.3	23.3	63.7
Neem (1.0%)	0.0	11.0	47.7
Dichlorvos (0.05%)	45.0	100.0	100.0
Control	0.0	0.0	4.3
CD (P=0.05)	3.2	1.6	1.9

Table 70. Effect of some biopesticides on *Pieris brassicae* larvae on cauliflower

Treatment	Number of larvae/plant		Leaf damage on 10th day (%)
	Pre-treatment	Post-treatment on 10th day	
Btk (1.0 kg/ha)	79.7	5.7 ab	64.0
B. bassiana (10^{11}conidia/l)	46.7	8.3 b	59.0
Eco Neem Plus (2ml/l)	62.3	0.0 a	74.7
DC-Tron Plus (0.75%)	58.3	10.5 b	67.7
DDVP (0.05%)	62.9	0.0 a	56.2
Control (water spray)	52.9	9.9 b	75.7

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

@ 1x10[13] conidia/ha caused 64% mortality on 12[th] day. The summer oil (DC Tron Plus @ 0.75) recorded a maximum of 80% mortality. Oxy methyl demeton (0.025%) recorded 81.3% mortality on the 3[rd] day and 100% on 6[th] day.

vii) Development of biocontrol-based IPM module against cabbage pests (SDAU)

A biocontrol-based IPM module (comprising the use of sex pheromone traps @ 5/ha each for *H armigera, S. litura* and *P. xylostella*, mechanical collection and destruction of egg masses and first instar larval masses of *S. litura*, six releases of *T. chilonis* @ 50,000/ha/week at the first observation of egg stage in the field and spray of NSKE (5%)) were compared with chemical module comprising of alternate spray with oxydemeton methyl (0.03%), quinalphos (0.05%) and endosulfan (0.07%) and farmers' practice at Sadarkrushinagar. The modules were evaluated against *H armigera, S. litura* and *P. xylostella.*

BIPM module was on par with farmers' practice with respect to the management of *H armigera* (3.09 and 3.74/plant), *S. litura* (3.98 and 4.39/plant) and *P. xylostella* (3.44 and 3.86/plant). Chemical treatment module resulted in lowest larval population of the three pests *H armigera* (2.79/plant), *S. litura* (3.40/plant) and *P. xylostella* (2.50/plant). Maximum yield was obtained in chemical module (280 q/ha) (Table 71).

3.14. BIOLOGICAL SUPPRESSION OF STORAGE PESTS

i) Evaluation of *Beauveria bassiana* and *Metarhizium anisopliae* isolates against bruchids (*Callosobruchus* spp.) in green gram in storage

PDBC

Six isolates of fungi belonging to *B. bassiana* (Bb-5a, Bb-6 and BB-11) and *M. anisopliae* (Ma-2, Ma-4, Ma-6) were tested against adults of *Callosobruchus* spp. Bioassay was carried out by treating the adult bruchids with aqueous spore suspension (1x10^9 spores/ml) or treating with the dry spore dust (1x10^9 spores/g) and releasing the adults into containers with green gram seed. *B. bassiana* isolates caused higher mortality (83.4-96.3%) and mycosis (62.3-82.3%), compared to *M. anisopliae* isolates, which caused 72.8-84.3% mortality and 32.3-61.6% mycosis. Bb-11 isolate of *B. bassiana* caused maximum mortality (96.3%) and mycosis (82.3%). From the mycosed beetle, the respective isolate of the fungus was reisolated. In control 39.7-40.2% mortality was observed without mycosis. Both types of inocula (aqueous spore suspension and dry spore dust) were found to be equally effective in causing mortality and mycosis.

Two kg of green gram in four plastic containers (@ 500g/container) were treated separately with spore dust of six isolates viz. Bb-5a, Bb-6 and Bb-11 and Ma-2, Ma-4, Ma-6 @ 10^9 spores/kg seed and 25 pairs of beetles were released into each container. The seeds treated with 0.1% groundnut oil served as standard check and the seeds without any treatment served as control. The containers with treated seeds were placed in a growth chamber set at 25^0 ± C and 70 ± % RH. The populations of live, dead and mycosed beetles were recorded at monthly intervals. After 4 months storage, among the fungal treatments, Bb-11 isolate showed the minimum number of live beetles (123), maximum dead beetles (385) and maximum mycosed beetles (58.7%). Un-treated seed had 347 live beetles and 281 dead beetles without mycosis. The grain damage observed in fungus-treated seeds was 96.8-99.2%, which was on par with the damage observed in control (99.6%). Treatment with 0.1% groundnut oil was found to be the best recording no

Table 71. Management of pest complex in cabbage

Treatment	Mean number of larvae/plant			Head damage at harvest (%)	Yield (q/ha)
	H. armigera	*S. litura*	*P. xylostella*		
BIPM	3.09	3.98	3.44	35.83	245.50
Chemical control	2.79	3.40	2.50	29.40	280.00
Farmers' practice	3.74	4.39	3.86	32.43	254.50
Control	4.43	7.27	5.70	41.26	171.50
CD (P=0.05)	0.30	0.13	0.46	4.29	21.10

live insects four months after the start of the experiment (Table 72).

PAU

The influence of three isolates in each of *B. bassiana* (Bb-5A, Bb-6& Bb-11) and *M. anisopliae* (Ma-2, Ma-4, Ma-6) against *Callosobruchus maculatus* in green gram and *Callosobruchus chinensis* in chickpea were evaluated in storage for four months. The green gram/ chickpea were mixed with the conidial dust @ 1g/ 500g seed in glass battery jars and one-day old adult beetles (25 pairs) were released into them and compared with control (without treatment) and 1% groundnut oil treatment (standard check).

The population build-up of *C. maculatus* in *B. bassiana* (1472-1740) and *M. anisopliae* isolates (1560-1610) treated green gram was at par with the control in storage (1679). However, the population of beetles did not build-up in 1% groundnut oil treated green gram seeds in storage (13.3).

Groundnut oil (1%) significantly affected the population build-up of *C. chinensis* in chickpea during storage as the number of adults was very low (13.3) compared to the control (1214). It was followed by all the three isolates of *M. anisopliae* (808-964) with no significant difference between the three. The population build-up of adults during storage after treatment with three isolates of *B. bassiana* (1182-1331) was at par with that of control (1214). Further, in case of both the species of bruchids, no mycosed adults were observed during the storage period and there was 100% grain damage in all the *B. bassiana* and *M. anisopliae* treatment and control (Table 73).

Table 72. Evaluation of *Beauveria bassiana* and *Metarhizium anisopliae* isolates against bruchids in green gram during storage

Fungal isolate	Number bruchids after 120 days of treatment		Grain damage (%)
	Live	Mycosed (%)	
Bb-5a	267	58.7	97.8
Bb-6	320	41.2	98.6
Bb-11	123	38.7	96.8
Ma-2	351	20.3	99.2
Ma-4	324	34.6	98.8
Ma-6	342	33.2	97.4
Groundnut oil (1%)	0	0.0	0.02
Control	347	0.0	99.6
CD (P=0.05)	86.3	7.9	4.8

Table 73. Evaluation of *Beauveria bassiana* and *Metarhizium anisopliae* isolates against *Callosobruchus maculatus* in green gram in storage

Treatment	Number of beetles after 2 months of storage	Number of beetles after 4 months of storage
Bb-5A	3359.8[b]	682.3[b]
Bb-6	4273.8[c]	630.5[b]
Bb-11	2285.0[b]	658.8[b]
Ma-2	3353.5[b]	592.3[b]
Ma-4	3007.5[b]	544.3[b]
Ma-6	3629.3[c]	532.0[b]
1% groundnut oil	1.0[a]	1.0[a]
Control	3644.3[c]	696.0[b]

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

3.15. MICROBIAL CONTROL OF WHITE GRUBS IN TURF (SKUAS & T)

The experiment was carried out at Royal Spring Golf Course, Srinagar. Seven treatments, viz. *Beauveria bassiana* local, *B. brongniartii* local and *Metarhizium anisopliae* local, each at the rate of $1x10^{12}$ spore/ml, chlorpyriphos (20 EC_ (4 l/ha), *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* each @ 5 billion ijs/ha and water as check were evaluated against third instar white grubs in $6m^2$ size plots with three replications in RBD.

The data revealed that the highest per cent mortality (83.5) was obtained with *M. anisopliae* local @ $1x10^{12}$ spore /ml on 30th day of application. Entomopathogenic nematodes, *S. carpocapsae* and *H. bacteriophora* were found to be least effective (Table 74).

3.16. POLYHOUSE CROP PESTS

i) Evaluation of fungal pathogens for the control of sucking pests of capsicum in polyhouses

MPKV

The experiment was conducted under polyhouse condition in Hi-Tech Floriculture Project, College of Agriculture, Pune on capsicum. The bioagents tested were *M. anisopliae* @ 10^{10} conidia/l, *V. lecanii* @ 10^{10} conidia/l, *B. bassiana* @ 10^{10} conidia/l, *Hirsutella thompsonii* formulation@ 10 g/l, methyl demeton (0.05%) and an untreated control. Spraying of *V. lecanii* was comparatively more effective than other fungal pathogens against thrips but not as effective on the chemical insecticide (Table 75).

Table 74. Efficacy of different fungal bioagents for the control of white grubs in turf

Treatment	Concentration (spores/ml or ijs/ha)	Per cent mean mortality (DAT)		Per cent reduction over control	
		10th	30th	10th	30th
Beauveria bassiana local	$1x10^{12}$	28.6	71.8	14.0	62.2
B. brongniartii local	$1x10^{12}$	32.1	62.1	18.6	32.9
Metarhizium anisopliae local	$1x10^{12}$	48.0	83.4	38.5	77.8
Steinernema carpocapsae	5 billion	12.9	22.4	7.26	8.4
Heterorhabditis bacteriophora	5 billion	15.9	33.5	1.1	11.3
Chlorpyriphos 20 EC	41 l/ha	53.3	83.4	43.9	67.4
Water (Control)	-	17.0	24.8	-	-
CD (P=0.05)	-	0.9	6.3	-	-

Each figure is a mean of three replications; DAT: Days after treatment

Table 75. Efficacy of fungal pathogens against thrips on capsicum in polyhouse in Pune

Treatment	Mean thrips population/ 3 leaves (days after spray)*		
	Pre-count	5	7
M .anisopliae	16.5^a	11.6^c	10.5^c
H. thompsonii	16.7^a	11.6^c	09.9^c
B. bassiana	15.3^a	12.8^c	10.0^c
V. lecanii	15.6^a	07.9^b	07.4^b
Methyl demeton	15.5^a	04.3^a	01.8^a
Control	16.5^a	19.5^d	25.6^d

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

KAU

The evaluation of fungal pathogens against aphids on capsicum was carried out at Vellanikkara area. Three sprays were applied in fungal treatments and a single spray in chemical control (imidacloprid 0.25 ml/l). Aphid count was minimum in imidacloprid treated plants followed by *B. bassiana* and *V. lecanii* (Table 76)

3.17. BIOLOGICAL SUPPRESSION OF WEEDS

Survey for the natural enemies of *Cyperus rotundus* (AAU, Jorhat)

The survey for the occurrence of natural enemies of *Cyperus rotundus* have been made in the Jorhat, Golaghat and Nagaon districts. The survey work revealed the occurrence of an unidentified borer pest on this weed and the incidence of the pest was very low.

Table 76. Efficacy of fungal pathogens against aphids on capsicum in polyhouse

Treatment	Mean number of aphids/leaf *						
	Pre	After 1st spray		After 2nd spray		After 3rd spray	
	count	5th day	7th day	5th day	7th day	5th day	7th day
Chemical control	27.8	0.3^{c}	0.2^{d}	0.0^{e}	0.1^{d}	0.4^{bc}	0.2^{c}
B. bassiana	13.8	1.5^{bc}	2.8^{c}	2.0^{d}	1.4^{cd}	0.3^{c}	0.5^{c}
M. anisopliae	27.2	5.2^{bc}	19.9^{a}	6.03^{bc}	16^{a}	2.1^{b}	3.3^{b}
H. thompsonii	31.4	7.7^{b}	6.5^{bc}	2.6^{cd}	3.8^{c}	0.8^{bc}	1.0^{bc}
V. lecanii	47.4	23.8^{b}	8.1^{b}	8.6^{b}	9.4^{ab}	1.2^{bc}	1.9^{c}
Verticel (*V. lecanii*)	33.0	1.6^{bc}	5.9^{bc}	3.2^{cd}	4.8^{bc}	1.8^{b}	0.6^{c}
Control	17.2	22.1^{a}	18.0^{a}	21.4^{a}	12.0^{a}	14.8^{a}	15.3^{a}

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

6. TECHNOLOGY ASSESSED, TRANSFERRED AND MATERIALS DEVELOPED

DNA sequences generated

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 brasiliensis* from USA internal transcribed spacer 2, complete sequence. LOCUS: 526 bp DNA. ACCESSION No. DQ381281.

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 evanescens* from Germany internal transcribed spacer 2, complete sequence. LOCUS: 517 bp DNA. ACCESSION No. DQ381280.

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 mawanzai* from Kenya internal transcribed spacer 2, complete sequence. LOCUS: 500 bp DNA. ACCESSION No. DQ381279.

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 dendrolimi* internal transcribed spacer 2, complete sequence. LOCUS: 540 bp DNA. ACCESSION No. DQ344045.

Jalali, S. K., Ashok Kumar, G., Niranjana, P., Venkatesan, T., and Lalitha, Y. 2006. Internal transcribed spacer-2 (ITS-2) sequence variation in *Trichogramma* species - *Trichogramma embryophagum* internal transcribed spacer 2, complete sequence. LOCUS: 593 bp DNA. ACCESSION No. DQ344044.

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 brassicae* internal transcribed spacer 2, complete sequence. LOCUS: 520 bp DNA. ACCESSION No. DQ314611.

Jalali, S. K., Ashok Kumar, G., Niranjana, P., Venkatesan, T., Wahab, S. and Lalitha,Y. 2006. Internal transcribed spacer-2 (ITS-2) sequence variation in *Trichogramma* species - *Trichogramma chilonis* internal transcribed spacer 2, complete sequence. LOCUS: 541 bp DNA. ACCESSION No. DQ220703.

Nagesh, M. 2005. Molecular identification of antagonistic fungi (*Pochonia chlamydosporia*). The genomic DNA of the native isolate of *P. chlamydosporia* (PDBC PC56) was extracted and sequenced the genes and the sequences were deposited with NCBI GenBank, Maryland, USA. The GenBank accession number is DQ417603.

Biocontrol demonstration in farmers' field

i. The technology on the control of spiralling whitefly with use of parasitoid *Encarsia guadeloupae* on guava

ii. Control of grape mealybug with use of predator *Cryptolaemus montrouzieri* demonstrated

iii. Control of sugarcane woolly aphid with predators

iv Biological control in *Bt* cotton and in organic rice

Computer-aided keys / web content

The website on the Coccinellidae of the Indian Subcontinent (Web page on Coccinellidae of the Indian region with image galleries of common species of coccinellids, their natural enemies and other assorted images (URL:www.angelfire.com/bug2/j_poorani/index.html) constructed last year was maintained and fresh content was added during the period under report. About 50 new photographs of coccinellids were uploaded to the website. An illustrated account of the general morphology of coccinellids was also included in the site during the period under report.

7. EDUCATION AND TRAINING

International

Name and designation	Training programme	Dates	Venue
Dr. J. Poorani Sr. Scientist	Invasion biology, Collections and Systematic of ladybird beetles	15-05-2005 to 21-05-2005	Washington DC, USA
Dr. R. J. Rabindra Project Director & Dr. P. Sreerama Kumar, Sr. Scientist	Pathways out of poverty	22-09-2005 to 23-09-2005	Cambridge, UK

National

Name and designation	Training programme	Dates	Venue
Dr. S. K. Jalali, Sr. Scientist Dr. S. Ramani, Sr. Scientist, Dr. B. Ramanujam Sr. Scientist, Dr. M. Nagesh, Sr. Scientist Dr. T. Venkatesan, Sr. Scientist	Capacity building programme for Indian Agricultural Research, Extension and Development Organisations in Globalised Economy	29-04-2005-30-04-2005	NAARM, Hyderabad
Dr. (Ms) K. Veena kumari, Sr. Scientist	Recent Advances in Agricultural Research Project Management	05-05-2005 to 25-05-2005	NAARM, Hyderabad
Dr.R. Rangeshwaran, Scientist (SS)	Bio-intensive IPM of insect pests and diseases of crops	09-11-2005 to 29-11-2005	DOR, Hyderabad
Dr. B. S. Bhummannavar, Principal Scientist, Mr. Satendra Kumar Technical Officer	Workshop on Administration and Management of Agricultural Research Stations	26-09-2005 to 30-09-2005	Agri-Science Knowledge Resource Group, ICRISAT, Hyderabad
Dr. K. Srinivasa Murthy, Senior Scientist	Capacity Building in Identification and Management of Mite Pests of Crops	21-09-2005 to 11-10-2005	UAS, GKVK, Bangalore
Dr. S. Sriram, Scientist (SS)	Microbial Diversity Analysis of Agriculturally Important Microorganisms	03-01-2006 to 25-01-2006	NBAIM, Kusmaur, Mau Nath Bhanjan
Ms. Shashikala S. Kadam	Effective Management of Technical Assistance in Agricultural Research	20-03-2006 to 25-03-2006	NAARM, Hyderabad.

8. AWARDS AND RECOGNITIONS

PDBC, Bangalore

Sunil Joshi, Scientist (SS) was awarded Ph. D degree in Agriculture Entomology by University of Agricultural Sciences, Bangalore

AAU, Anand

Jani, J. J., was awarded Ph. D. degree in Microbiology by Bhavnagar University, Bhavnagar.

Dr. D. N. Yadav was been awarded "Dr. R. L. Srivastava memorial National Award" at National conference during September 26-29, 2005 at Maharana Pratap University of Agriculture and Technology, Udaipur.

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

Research projects – Lateral sources at Project Directorate of Biological Control, Bangalore

DBT-Funded projects

1. Isolation, purification and characterization of novel insecticidal toxins from *Photorhabdus luminescens* and *Xenorhabdus* spp. of bacteria from entomopathogenic nematodes
2. Development of biocontrol strategies for the management of sugarcane woolly aphid, *Ceratovacuna lanigera*.
3. Development of a strain of *Trichogramma chilonis* tolerant to newer insecticides and high temperature
4. Evaluation of arbuscular michorrhizal fungi and entomopathogenic nematode cruisers interaction on the reproduction and development of root knot nematode, *M. incognita*
5. Management of cardamom root grub, *Basilepta fulvicorne* with entomogenous nematodes
6. Development of invert-emulsion formulation of *Trichoderma harzianum* with prolonged shelf-life and enhanced biocontrol potential

ICAR Cess-fund projects

1. Development of commercial formulation of antagonistic fungi (*Paecilomyces lilacinus* and *Verticillium chlamydosporium*) for biological control of *Meloidogyne incognita* and *Rotylenchulus reniformis* (ICAR-Cess fund)
2. Development of a strain of *Trichogramma chilonis* tolerant to newer insecticide and high temperature
3. Network project of biosystematics

DAC-funded project

1. Technology Mission for Cotton

DFID (UK)-funded project

1. Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii*: implementation phase

10. AICRP / COORDINATION UNIT / NATIONAL CENTRES

With a view to fulfil the mandate effectively and efficiently, the Project Directorate is functioning with the following State Agricultural University-based and ICAR Institute-based centres.

State Agricultural University-based centres

i.	Acharya N. G. Ranga Agricultural University	Hyderabad
ii.	Anand Agricultural University	Anand
iii.	Assam Agricultural University	Jorhat
iv.	Dr.Y.S.Parmar University of Horticulture and Forestry	Solan
v.	Gobind Ballabh Pant University of Agriculture and Technology	Pantnagar
vi.	Kerala Agricultural University	Thrissur
vii.	Mahatma Phule Krishi Vidyapeeth	Pune
viii.	Punjab Agricultural University	Ludhiana
ix.	Sher-e-Kashmir University of Agricultural Science & Technology	Srinagar
x.	Tamil Nadu Agricultural University	Coimbatore

ICAR Institute-based centres

i.	Central Plantation Crops Research Institute	Kayangulam
ii.	Central Tobacco Research Institute	Rajahmundry
iii.	Indian Agricultural Research Institute	New Delhi
iv.	Indian Institute of Horticultural Research	Bangalore
v.	Indian Institute of Sugarcane Research	Lucknow
vi.	Sugarcane Breeding Institute	Coimbatore

With a view to fulfill the mandate given, under the AICRP on Biocontrol the programmes distributed among six ICAR Institutes and ten State Agricultural University (SAUs) in addition to seven voluntary centres as coordinating centres based on infra-structural facilities and expertise available as follows:

Headquarters

Project Directorate of Biological Control, Bangalore	Basic research

ICAR Institute based centres

Regional Station (CPCRI), Kayangulam	Coconut

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

11. LIST OF PUBLICATIONS

Research papers published in refereed scientific journals

(a) Project Directorate of Biological Control, Bangalore

Bajpai, N. K., Ballal, C. R., Rao, N. S. Singh, S. P. and Bhaskaran, T. V. 2005. Competitive Interaction between two ichneumonid parasitoids of *Spodoptera litura*. *Biocontrol*, **51**: 419-438.

Bakthavatsalam, N. and Tandon, P. L. 2006. Behavioural response of strains of *Trichogramma chilonis* Ishii to the kairomonal substances. *Journal of Biological Control*, **20**: 13-17.

Ballal, C. R., Srinivasan, R. and Chandrashekhar, B. 2005. Evaluation of quality of *Trichogramma chilonis* Ishii from different production units in India. *Journal of Biological Control*, **19**: 1-8.

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

Hussaini, S. S., Nagesh, M., Rajeshwari, R. and Dar, M. H. 2005. Effect of antidesiccants on survival and Pathogenicity of some indigenous isolates of EPN against *Plutella xylostella Annals of Plant Protection Sciences*, **13**: 179-186.

Hussaini, S. S., Nagesh, M. and Shakeela, V. 2005. Survival of infective juveniles of Entomopathogenic nematodes under storage and their infectivity against *Galleria mellonella* and *Spodoptera litura*. *Indian Journal of Plant Protection*, **33**: 68-71.

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Hussaini, S. S., Shakeela V. and Dar, M.H. 2005. Influence of temperature on infectivity of Entomopathogenic nematodes to black cutworm, *Agrotis ipsilon* (Hufnagel) larvae *Journal of Biological Control*, **19**: 51-58.

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., Bhaskaran, T.V. and Lalitha, Y. 2005. Preliminary attempt at biological control of coconut black headed caterpillar, *Opisina arenosella* Walker using two *Trichogramma* species. *CORD*, **21**: 1-6.

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Kumar, P. S., Palakshappa, M. G. and Singh, Leena. 2005. Effect of polyethylene glycol on the biomass characteristics of *Trichoderma harzianum* and *T. viride* in liquid culture. *Indian Phytopathology*, **58**: 466-469.

Kumar, P. S., Ramani, S. and Singh, S. P. 2005. Natural suppression of the aquatic weed

Salvinia molesta D.S. Mitchell, by two previously unreported fungal pathogens. *Journal of Aquatic Plant Management*, **43**: 105-106.

Kumar, P. S., Rabindra, R. J., Usha Dev, Puzari, K. C., Sankaran, K. V., Khetarpal, R. K., Ellison, C. A. and Murphy, S.T. 2005. India to release the first fungal pathogen for the classical biological control of a weed. *Biocontrol News and Information*, **26**: 71N-72N.

Nagesh, M., Hussaini, S. S. and Chidanandaswamy, B.S. 2005. Incidence of root-knot nematode, *Meloidogyne incognita* on gherkin, *Cucumis sativus* and yield losses. *Indian Journal of Plant Protection*, **33**: 309-311.

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(b) IISR, Lucknow

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(c) IIHR, Bangalore

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Gopalakrishnan, C. and Gangavisalakshy, P.N. 2005. Field efficacy of commercial formulations of Bacillus thuringiensis var. Krustaki against *Papillo demoleus* L. on citrus. *Entomon*, **30**: 93-95.

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Mani, M. and Krishnamoorthy, A. 2002. Selectivity of different pesticides to citrus mealybug parasitoid *Coccidoxynoides peregrina* (Timberlake) *Journal of Insect Science*, **15**: 49-52.

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(d) **SBI, Coimbatore**

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(e) **AAU, Jorhat**

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(f) **YSPUH&F, Solan**

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(g) **KAU, Thrissur**

Lyla, K. R., Pathummal Beevi, S. and Ushakumari, R. 2005. Record of woolly aphid, *Ceratovacuna lanigera* Zch. (Homoptera: Aphididae) and its natural enemies in Kerala. *Insect Environment*, **11**: 126.

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12. LIST OF APPROVED ONGOING PROJECTS

I Basic Research

Project Directorate of Biological Control, Bangalore

1. Biosystematic studies on predatory coccinellids
2. Development of identification keys for important families of insect parasitoids and predators
3. Biosystematic studies on Indian Tachinidae
4. Introduction and studies on exotic natural enemies of some important crop pests and weeds
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. Studies on biological control of sugarcane woolly aphid
9. Herbivore induced plant synomones and their utilization in enhancement of the efficiency of natural enemies.
10. Host derived kairomones to enhance the efficiency of natural enemies
11. Development and evaluation of improved strains of trichogrammatids, *Cheilomenes sexmaculata* and *Chrysoperla carnea* tolerant to insecticides, temperature and high host searching ability
12. Development and formulation of artificial diets for the rearing of coccinellids and anthocorids
13. Development and evaluation of artificial diets for *Opisina arenosella* and *Plutella xylostella* and studies on host-parasitoid interrelations
14. Development and use of insect viruses for the management of major pest complex of cruciferous crops
15. Development of improved formulations of NPV for management of *Helicoverpa armigera* and *Spodoptera litura* in tomato
16. Identification of effective entomofungal pathogens for the management of sugarcane woolly aphid and their evaluation
17. Identification of pathogens of phytophagous mites and assessment of their potential in microbial control
18. Identification of *Trichoderma* isolates with enhanced biocontrol potential
19. Efficient formulations of *Trichoderma* sp. and entomofungal pathogens with prolonged shelf-life
20. Isolation, characterization and toxicity testing of indigenous *Bacillus thuringiensis* strains against lepidopterous pests
21. Mass production, formulation and field-testing of entomopathogenic nematodes against important lepidopteran pests
22. Biological suppression of plant parasitic nematodes exploiting antagonistic fungi and bacteria in specific cropping systems
23. Software development for identifying and suggesting biosuppression measures for different crop pests using personal computer
24. Development of national information system on biological suppression of crop pests
25. Developing a data base on microbial biocontrol agents

Other sources

1. Commercialization of bioagent mass-production technologies in intensive cotton districts (TMC MM 3.3, Cotton Technology Mission; DAC)
2. Evolving and testing superior strains of *Steinernema* sp. and *Heterorhabditis* sp. against *Spodoptera litura* in field (ICAR-Cess)
3. Isolation, purification and characterization of novel insecticidal toxins from *Photorhabdus luminescens* and *Xenorhabdus* spp. of bacteria from entomopathogenic nematodes (DBT)
4. Development of biocontrol strategies for the management of sugarcane woolly aphid, *Ceratovacuna lanigera* (DBT)
5. Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii* (DFID, UK)
6. Development of commercial formulation of antagonistic fungi (*Paecilomyces lilacinus* and *Verticillium chlamydosporium*) for biological control of *Meloidogyne incognita* and *Rotylenchulus reniformis* (ICAR-Cess fund)

Indian Agricultural Research Institute, New Delhi

1. Basic studies and maintenance of *Bacillus thuringiensis* strains
2. Studies on formulations of microbial pesticides based on baculoviruses and *Bacillus thuringiensis*

Applied Research

I BIOLOGICAL CONTROL OF PLANT DISEASES & NEMATODES USING ANTAGONISTIC ORGANISMS

Testing of bioefficacy of oil based and talc based formulations of biocontrol agents against foliar diseases (Rice : GBPUA & T, PAU & AAU (J) ; Tomato:GBPUA & T, AAU (A) ; Pea : GBPUA & T & PAU).

In vitro compatibility between entomopathogens and fungal and bacterial antagonists. (GBPUA &T and PDBC).

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).

Large scale field-testing of *Trichoderma* at farmers' field (GBPUA & T).

Shelf-life of *Trichoderma* and *Pseudomonas* formulations (GBPUA & T and PDBC).

Biological control of plant parasitic nematode, *Meloidogyne* spp. in tobacco nurseries (CTRI, Hunsur Station).

Biological control of pigeonpea cyst nematodes and disease complex (AAI, AAU (A), and TNAU).

Evaluation of *Trichoderma* spp. against soil borne and foliar diseases in groundnut (AAU (A)).

Biological control of root knot and other plant parasitic nematodes in citrus (AAU (A)).

Biological control of cyst nematodes in potato (Regional Station CPRI, Ooty).

Biological control of post-harvest fruit rot in Mango, Guava and Papaya using yeasts (PDBC, AAU (A) and GBPUA & T).

II BIOLOGICAL SUPPRESSION OF SUGARCANE PESTS

Bio-intensive pest management practices for sugarcane scales (CCSHAU & IISR).

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

Field evaluation of *Trichogramma chilonis* against Plassey Borer (AAU (J)).

Demonstration on the use of *T. chilonis* (temperature tolerant strain) against early shoot borer at 2 locations (PAU & NCIPM)

Biological suppression of white grubs using FYM enriched with *Beauveria bassiana* (GBUA&T)

Biological suppression of sugarcane woolly aphid

Population dynamics of SWA and its natural enemies (TNAU, AAU (J), ANGRAU, CCSHAU)

Biology of predators - *Dipha aphidivora* (TNAU and MPKV)

Micromus igorotus (PDBC)

Predatory potential: *Dipha aphidivora* (TNAU); *Micromus igorotus* (PDBC)

Mass production of predators in shade net/ laboratory: *Dipha aphidivora* (MPKV, SBI, ANGRAU and AAU (A)); *Micromus igorotus* (PDBC, TNAU, ANGRAU and AAU (A))

Alternate host rearing of the predators (PDBC)

Effect of Agronomic Practices on incidence of SWA (TNAU, MPKV, SBI and ANGRAU)

Field release and evaluationa: *Dipha aphidivora* (AAU (A) and TNAU) *Micromus igorotus* (AAU (A) and SBI)

Interaction between *Dipha aphidivora* and *Micromus igorotus* (TNAU, PDBC and ANGRAU)

Field demonstration of biocontrol using *D. aphidivora* and *M. igorotus* (TNAU, MPKV, SBI, AAU (J), ANGRAU, AAU (A) and PDBC)

Development of IPM strategy (TNAU, SBI, IISR, AAU (A), ANGRAU and NCIPM)

Colonization of *Encarsia flavoscutellum* (TNAU, IISR, AAU (J), ANGRAU, AAU (A))

Monitoring and forecasting of SWA (TNAU, SBI, IISR and ANGRAU)

Yield loss assessment (SBI and IISR)

III BIOLOGICAL SUPPRESSION OF COTTON PESTS

BIPM for *Bt* cotton (ANGRAU, AAU(A), TNAU, MPKV and UAS, Dharwad)

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)

Enhancement of Natural Enemies Population in cotton by habitat manipulation (PAU, ANGRAU and AAU (A))

IV BIOLOGICAL SUPPRESSION OF TOBACCO PESTS

Biological control of *Spodoptera exigua* in tobacco nurseries with bio-pesticides (CTRI)

Validation of trap crop and border crop modules for the management of lepidopteran pests on tobacco (CTRI)

Studies on the efficacy of adjuvants in Sl NPV / HaNPV persistence and their impact on tobacco quality (CTRI)

V BIOLOGICAL SUPPRESSION OF PULSE CROP PESTS

Evaluation of DOR *Bt* against the Pod borers (TNAU, ANGRAU, AAU (A) and UAS (D))

Evaluation of BIPM package on soybean (CTRI and NRCS)

VI BIOLOGICAL SUPPRESSION OF RICE PESTS

Evaluation of DOR *Bt* against leaf folder (KAU, GBPUA&T, AAU(J) & PAU)

Validation of biointensive pest management practices in organic rice production (PAU, KAU, AAU (J), GBPUA &T and NCIPM)

Validation of BIPM practices against pest complex of rice (KAU)

VII BIOLOGICAL SUPPRESSION OF OILSEED CROP PESTS

Identification of natural enemies of mustard saw fly for use in biocontrol (AAU (A), PAU and AAU (J))

Biological control of mustard sawfly (AAU (A) and AAU (J))

VIII BIOLOGICAL SUPPRESSION OF COCONUT PESTS

Evaluation of *Trichogramma embryophagum*, *Goniozus nephantidis* and *Cardiastethus exiguus* against *Opisina arenosella* (KAU & CPCRI)

Establishment of *Eriborus trochanteratus* against *Opisina arenosella* (PDBC and CPCRI)

Validation of biological suppression of *Oryctes rhinoceros* in homestead garden (KAU)

IX BIOLOGICAL SUPPRESSION OF TROPICAL FRUIT CROP PESTS

Population dynamics of soft green scale *Coccus viridis* and its natural enemies on sapota (IIHR)

Evaluation of *Verticillium lecanii* against sapota green scale *Coccus viridis* (IIHR)

Efficacy of different doses of *Verticillium lecanii* against mango hoppers (IIHR)

Biology of *Isyndus heros*, a predator of mango hoppers (IIHR)

Field evaluation of natural enemies against mango hoppers (IIHR and CISH)

Biological suppression of pomello mealybug *Planococcus citri* (IIHR)

Effect of off-season release of *Cryptolaemus montrouzieri* to suppress the mealybug on custard apple on the main season (IIHR)

Safety of newer pesticide to *Cryptolaemus montrouzieri* (IIHR)

Effect of commonly used pesticides in the flowering stage on the reduviid predator *Isyndus heros* (IIHR)

Efficacy of the aphelinid parasitoid *Encarsia guadeloupae* in the suppression of spiraling whitefly under glass house condition (IIHR)

Studies on the natural enemies of thrips on pomegranate, mango and grapes (IIHR)

Evaluation of *Bt* formulations against leaf miner on acid lime and pomello (IIHR)

Impact of naturally occurring predators in the suppression of amla aphid, *Schoutedenia emblica* (IIHR)

Demonstration on the performance of Australian ladybird beetle *Cryptolaemus montrouzieri* in the suppression of grape mealybug (IIHR)

Mass rearing of *Encarsia guadeloupae* on spiralling whitefly (IIHR)

Collection and identification of the natural enemies of sapota seed borer, *Trymalitis margarias* and mango fruit fly *Bactrocera dorsalis* (IIHR)

Survey and biocontrol of Guava fruit borer *Conogethes punctiferalis* (RARS, UAS (D) Raichur)

XBIOLOGICAL SUPPRESSION OF TEMPERATE FRUIT CROP PESTS

Development of bio-intensive IPM for San Jose Scale, *Quadraspidiotus perniciosus* in apple ecosystem. (SKUAS & T and Dr. YSPUH & F)

Field evaluation of mass released *Trichogramma embryophagum* against the codling moth, *Cydia pomonella* on apple (SKUAS & T)

Evaluation of fungal pathogens against wooly aphids (Dr.YSPUH & F) and mites (SKUAS & T) on apple

Mass production of predatory mites (Dr.YSPUH & F)

XI BIOLOGICAL SUPPRESSION OF VEGETABLE CROP PESTS

Biological control of *Diaphania indica* infesting gerkhins/cucurbits (IIHR)

Biological control of DBM on cabbage /cauliflower (IIHR)

Biological control of cabbage web worm, *Crocidolomia binotalis* (IIHR)

Evaluation of EPN against brinjal shoot and fruit borer (IIHR, KAU, PAU)

Standardization of mass rearing of *Thrips tabaci* (IIHR)

Feeding potential of *Orius tantillus* on chilli thrips (IIHR)

Management of DBM on seed crop of cauliflower using *Diadegma fenestilalis* (Dr.YSPUH & F)

Microbial control of *Trialeurodes vaporariorum* using fungal pathogen (Dr.YSPUH & F.)

Evaluation of DOR *Bt* against fruit borers of brinjal and okra (KAU)

Effectiveness of various microbial pesticides and a summer oil against *Pieris brassicae* (Lepidoptera:Pieridae) on kale / knol khol (SKUAS & T and Dr.YSPUH & F)

Development of Bio-control based IPM module against cabbage pests (SDAU)

Biological suppression of white grubs using FYM enriched with *Beaveauria bassiana* and *Metarhizium anisopliae* (GBPAU & T)

XII BIOLOGICAL SUPPRESSION OF STORAGE PESTS

Evaluation of *Beauveria bassiana* and *Metarhizium anisopliae* isolates against bruchids (*Callosobruchus* spp.) in green gram in storage (PDBC & PAU)

XIII BIOLOGICAL SUPPRESSION OF PESTS IN TURF GRASS

Microbial control of white grubs in turf (SKUAS & T)

XIV BIOLOGICAL SUPPRESSION OF PESTS IN POLYHOUSES

Biological control of thrips, aphids and mites in polyhouses (MPKV, KAU, PDBC and NCIPM)

Survey for pest problems: Monthly visits to three selected polyhouses to document the pest problems

Evaluation of fungal pathogens for the control of sucking pests (crops: capsicum/tomato/rose)

XV BIOLOGICAL SUPPRESSION OF WEEDS

1. Survey for the natural enemies of *Cyperus rotundus* (KAU, TNAU, AAU (A), AAU (J), PAU and NRCWS)

13. CONSULTANCY, PATENTS, COMMERCIALIZATION OF TECHNOLOGY

- EAG and GC-MS analysis for samples received from various organizations
- Quality test for biopesticides
- Bioassay of *Bt* proteins against lepidopterous pests
- *In vitro* evaluation of phenolics, flavonoids and maize leaf extracts for toxicity to *Chilo partellus*

14. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE

Tenth Research Advisory Committee Meeting held on 18 - 19 August 2005

1. Organic farming is gaining importance and bioagents being important component, efforts need to be made to identify pest-wise biocontrol agents, which can be used cost-effectively for eco-friendly management of pests and diseases.
2. Studies on plant growth promoting biocontrol agents may be further strengthened for use in management of fungal and bacterial pathogens.
3. Use of magnetic shaker method along with fermentor may be tried for multiplication of antagonists.
4. *Hirsutella thompsonii* can be tried in polyhouse conditions for the control of phytophagous mites.
5. Research efforts may continue to identify suitable biocontrol agent for the control of coconut mite on priority basis as the coir industry also indirectly depend on coconut production.
6. Research on biocontrol of stored grain pests may be initiated and these studies need to be taken up in godowns and large storage bins.
7. Molecular techniques may be utilized in biocontrol research as a tool to characterize and map the genetic diversity of natural enemies as well as their respective pests to enhance biocontrol.
8. More emphasis may be given for the biological control of plant diseases and plant parasitic nematodes.
9. Efforts are to be made for semi-automation of production of biocontrol agents. A linkage may be developed with Central Institute for Agricultural Engineering, Bhopal in production units for mechanization.
10. Mass production technology for EPN has been standardized and now efforts may be made to transfer the technology to commercial production units.
11. Feasibility of utilizing the Transfer of Technology Units of Agricultural Universities may be explored for increasing the awareness and up take of biocontrol technologies by the farmers.
12. Efforts need to be made to take the services of NGOs in popularizing biocontrol agents particularly in promoting organic farming.
13. Commercialization of biocontrol agents need to strengthened as it has been done in *Bt*.
14. Front line demonstrations to be laid out on priority basis through the AICRP centres located at ICAR Institutions and State Agricultural Universities.
15. Data on impact on the utilization of biocontrol agents in different cropping systems may be collected.
16. Implication of basic and strategic research in addition to the priorities and issues of PDBC may be looked into along with the latest IPR issues.
17. Information on the safety of fungal biocontrol agents may be compiled and a brief note may be submitted to the Assistant Director General (Plant Protection), ICAR, New Delhi.
18. A proposal may be sent to the Council for a short visit of one or two scientists from PDBC to biocontrol production units in Switzerland for getting first hand information on mechanization of mass production, packing, storage and transport of biocontrol agents.

19. One field visit can be organized for the RAC Members to see the impact of usage of biocontrol agents against insect pests and diseases.

Interactive meeting

Interactive meeting with Zonal Coordinators on utilisation and demonstration on the efficacy of potent natural enemies in different crop ecosystem under various agro-climatic zones on 28-01-2006.

Institute Research Council Meeting held on 6 April 2005

The Institute Reseach Council Meeting was held on 6 April 2005 under the Chairmanship of Dr. R.J.Rabindra,, Project Director, in the presence of Dr. O.P.Dubey, Assistant Director General (PP), ICAR, New Delhi. The following staff members attended the meeting.

Dr. R.J.Rabindra, Project Director welcomed all and stressed the need for monitoring and evaluation of the research programmes to meet the 10th Plan objectives and to reach the goal as per Perspective Plan (Vision 2025). The specific objective is to translate the effective biocontrol agents/technologies for adoption by stake-holders and the end-users-farmers.

The scientists 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:

Biosystematic studies on predatory coccinellids - Dr. J. Poorani

Biosystematic studies on Indian Tachinidae - Dr. S. Ramani

Introduction and studies on exotic natural enemies of some important crop pests and weeds - Dr. B.S. Bhumannavar

Development of interactive identification key for important families of insect parasitoids and predators - Dr. J. Poorani

Rearing and evaluation of natural enemies with special reference to scelionid, braconid, ichneumonid and anthocorid groups - Dr. C.R. Ballal

Development of mass production techniques for dipteran (Diptera: Cecidomyiidae) and acarine (Arachnida: Acarina) predators for use in biological control programmes) - Dr. Prashant Mohanraj

Mass production and evaluation of *Micromus* sp Development of novel mass production, storage and packaging techniques for *Cryptolaemus montrouzieri* - Mr. Sunil Joshi

Development and use of insect viruses for the management of major pest complex of cruciferous crops - Dr. K. Narayanan

Development of improved formulations of NPV for management of *Helicoverpa armigera* and *Spodoptera litura* in tomato - Dr. K. Veenakumari

Evaluation of fungal pathogens against thrips on onion and garlic - Dr. B. Ramanujam

Identification of effective entomofungal pathogens for the management of sugarcane woolly aphid and their evaluation - Dr. B. Ramanujam

Identification of *Trichoderma* isolates with enhanced biocontrol potential - Dr. S. Sriram

Efficient formulations of *Trichoderma* sp. and entomofungal pathogens with prolonged shelf-life - Dr. S. Sriram

Mass production, formulation and field testing of entomopathogenic nematodes against important lepidopteran pests - Dr. S.S. Hussani

Biological suppression of plant parasitic nematodes exploiting antagonistic fungi and bacteria in specific cropping systems - Dr. M. Nagesh

Identification of pathogens of phytophagous mites and assessment of their potential in microbial control - Dr. P. Sreerama Kumar

Herbivore induced plant synomones and their utilization in enhancement of the efficiency of natural enemies - Dr. P.L. Tandon

Host derived kairomones to enhance the efficiency of natural enemies - Dr. N. Bakthavatsalam

Development and evaluation of improved strains of trichogrammatids, *Cheilomenes sexmaculata* and *Chrysoperla carnea* tolerant to insecticides, temperature and high host searching ability - Dr. S.K. Jalali

Development and formulation of artificial diets for the rearing of coccinellids and anthocorids - Dr. T. Venkatesan

Development and evaluation of artificial diets for *Opisina arenosella* and *Plutella xylostella* and studies on host-parasitoid interrelations - Dr. K.S. Murthy

Software development for identifying and suggesting biosuppression measures for different crop pests using personal computer - Dr. S.R. Biswas

Development of national information system on biological suppression of crop pests - Mr. S.R. Biswas

Developing a data base on microbial biocontrol agents - Ms. M. Pratheepa

Technical and Documentation Cell - Dr. N. S. Rao

Dr. O.P.Dubey in his special remarks appreciated the good work done by the scientists of PDBC in the past and suggested that the tempo should be maintained if not accelerated for bringing out cost-effective technologies.

Institute Management Committee Meetings

The Chairman welcomed all the Members to the Thirteenth Management Committee held on 4th 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 Administrative, Finance & Accounts matters were discussed. The expenditure incurred under Plan and Non-Plan during 2005-06 and the expenditure incurred up to 31.3.2006 were discussed. The revenue realized during 2005-06 was presented. It was suggested to clarify the revenue under the revised estimate for the year 2005-06.

The Action taken on the recommendation of XII Management Committee meeting held on 11th 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. The change of equipment is shown below :

Existing items	Proposed equipment	Action taken
Video conference unit costing Rs.5, 00,000	Laboratory furniture	Purchased
Beta scintillation unit	Vacuum sealing unit	Opened the LC
	Bubble diet making machine	Unable to procure
Ultrasonicator	Water activity meter	Orders placed
	Deep freezer $-20°$	Purchased
	CFC Free refrigerator	Under process

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.

b) Proposal for replacement of certain equipment

Replacement of equipment in place of condemned equipment

Existing equipment	To be replaced with	Approximate cost (Rs.)	Justification
Network electronic typewriter – 2 Nos	Personal computer	1,00,000	This is needed for carrying out network and AICRP Coordination work and library for database
HAL Telex machine	Fax machine	15000	Telex machine is not used at present and needs to be replaced with fax machine for the technical cell as much correspondence is made with the AICRP centers
LCD Projector– 2 Nos.	LCD projector	4,00,000	Existing LCD projectors are outdated and spares are not available so they have to be replaced with new LCD projectors for regular training programmes and meetings
Laboratory oven Autoclave Rotary shaker	Laboratory oven Autoclave Oribital shaker	40,000 50,000 75,000	These are needed for pathological work
Tulaman balance	Electronic balance	25,000	For regular weighing of diet ingredients and culture media components
Image analysis system attached to microscope	New image analysis system attached to microscope	5,00,000	This is needed for taking digital pictures and other pictures of nematodes
Table top autoclave	New Table top autoclave		For regular sterilization work in EPN laboratory
UPS	UPS	50,000	For back-up for important equipments in EPN lab
Binocular microscope	New Stereozoom microscope	2,00,000	For identification of trichogrammatids
Environmental chamberNew	Environmental chamber	4,00,000	For developing temperature tolerant strains of parasitoids
Colour monitor for computer	New Colour monitor for computer	8,000	For library

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 U.A.S., 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. Additional sanction is sought for the following items of work.

Farm development:

S. No.	Item of work	Sanctioned in X plan	Additional sanction required
1.	Rain water harvesting system, central road & Drainage channels	6.00	29.65
2.	Street lights	1.50	8.50
3.	Compound wall & road	14.50	11.75
4.	Glasshouse (5x5 m)	5.00	15.20
5.	Construction of Farm Office, Store Room and Field Laboratories	11.31	7.30

Recommendation

After detailed discussion, the committee has recommended for the additional sanction under works and equipment.

15. PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA, ETC. IN INDIA AND ABROAD

Project Directorate of Biological Control, Bangalore

Dr. R. J. Rabindra attended:

"Workshop on Sugarcane Woolly Aphid – Harmonizing various research programmes for focussed efforts on development of successful strategies", from 4-5 April 2005.

"Workshop on Management of Change in AICRPs 2005" held from 16-18 May 2005 at NASC Auditorium, New Delhi and presented a paper on "Strategies for commercialization of product and technology" on 17 May 2005.

"Workshop on Biocontrol of the weed *Mikania* in Kerala" held at KFRI, Peechi on 24 November 2005.

"Workshop on biocontrol of *Mikania*" held at AAU, Jorhat, on 28 November 2005.

"Brainstorming Session on Organic Farming" held at IIVR, Varanasi on 2 February 2006.

"Brainstorming Session on *Uzi* Fly Management" sponsored by CSRTI and organized at PDBC on 10 February 2006.

"Workshop on Early Warning Systems for Forest Invasive Species" held at KFRI, Peechi, on 22 February 2006and reviewed the progress of work of *Mikania* project at KFRI, on 23 February 2006.

"Pathways out of Poverty" held at Cambridge, UK from 22- 23 September 2005.

"Conference on Soil Biology" and delivered a lecture on "Soil biology and biological control" at Tanjore on 5 October 2005. Visited National Research Centre on Banana, Tiruchirapalli on 6 October 2005 and discussed the biological control of banana pests and diseases with the scientists

"Conference on Post-Tsunami Plant Protection in Andaman & Nicobar Islands" held at CARI, Port Blair, on 15 October 2005 and presented a paper entitled "Biological control of crop pests and diseases – prospects and future" during the conference.

"International Grain Legume Conference" held at New Delhi on 20 October 2005. In the afternoon held discussions with the following officials at the ICAR. Director (Finance) for release of additional TA grant. ADG (PP) release of grants relating to expenditure in respect of AICRP and AINP projects. ADG (PIM) on revision of EFC proposals discussed *Mikania* project at the NBPGR, New Delhi.

"International Conference on Biotechnology for Sustainable Agriculture and Agro-industry" held on 11 March 2006 at Hyderabad and presented a paper entitled "Biotechnology and biological control."

"National Conference on Agrobiodiversity" organized by Biodiversity Authority in India at Chennai on 13 February 2006 and delivered a lecture on "Biodiversity and biological control."

"Ninth Group Meeting of the AINP on Acarology" held at PAU, Ludhiana, on 12 April 2005.

"Third Meeting of the Research Advisory Committee" of Central Institute of Temperate Horticulture, Srinagar, from 4-5 May 2005.

"Discussion meeting on the Classical biological control of *Mikania micrantha* using

Puccinia spegazzinii called by the Plant Protection Adviser to the Govt. of India at Shastri Bhavan, New Delhi on 15 June 2005.

"First meeting of the Expert Panel on Organic Farming" held at National Centre of Organic Farming (NCOF), Ghaziabad, on 27 June 2005.

"Selection committee meeting" held in the chamber of the Chief Secretary, Chief Secretariat, Goubert Avenue, Pondicherry as an ICAR nominee, on 30 June 2005.

"First meeting on Human Resource Development in Biotechnology" under the chairmanship of DDG (CS) at NBPGR, New Delhi, from 7-8 July 2005 .

"First meeting of the working group III Integration of basic, strategic, anticipatory and applied research for the management of change in AICRPs" under the chairmanship of DDG (CS) at ICAR, Krishi Bhavan, New Delhi on 13 July 2005.

"Meeting on commercialization of products related to parasites, predators and antagonists" held at the NCIPM, New Delhi, on 20 July 2005.

"IPM meet" organised by Plant Protection Advisor, Government of India at New Delhi, on 26 July 2005.

"Fifth Meeting of the Task Force on Biopesticides and Crop Management" held at Conference Hall, The Energy and Resources Institute, Habitat Centre, Lodi Road, New Delhi, on 22 August 2005.

"Twenty-second meeting" of the RAC of Central Sericultural Research and Training Institute, Mysore at Mysore from 24- 25 October 2005.

"Meeting of the Crop Science Division" chaired by the DDG (CS) at ICAR New Delhi, on 16 January 2006.

Dr. P. L. Tandon attended:

"Fourteenth Biocontrol Worker's Group Meeting" at Sugarcane Breeding Institute, Coimbatore from 21-23 June 2005 and Chaired the Session.

"National Conference on IPR and Management of Agricultural Research" organized by the ICAR and held at New Delhi, from 27-29 August 2005.

"Twentieth Meeting of ICAR Regional Committee No. VIII" at Chennai, on 23-24 December 2005.

"National Symposium on Biotechnology and Insect Pest Management" held at Entomology Research Institute, Loyola College, Chennai from 2-3 February 2006. Chaired the session on "Insect Resistance Transgenic Crops" and also presented an invited Lead Paper on "Biotechnology- a versatile tool in biological control of crop pests using parasitoids and predators."

"The Premier Workshop on The Right to Information Act 2005" organized by the Director, National Institute of Public Administration at Bangalore, from 23-24 January 2006.

Dr. K. Veenakumari attended:

The summer school on "Recent Advances in Agricultural Research Project Management" held at NAARM, Hyderabad, from 5-25 May 2005.

Dr. R. Rangeshwaran attended:

The 21-day winter school on "Biointensive Integrated Management of Insect Pests and Diseases of Crops" held at the Directorate of Oilseeds Research, Hyderabad from 9-29 November 2005. Delivered a lecture on the topic "Role of endophytic bacteria in biological control and induction of systemic resistance" during the winter school.

Dr. P. Sreerama Kumar attended:

"Interactive meeting of the ICAR-CABI collaborative project on Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii*: Implementation phase" at the National Bureau of Plant Genetic Resources, New Delhi, from 25-26 April 2005.

"Meeting to review the dossier on "*Puccinia spegazzinii* de Toni (Basidiomycetes: Uredinales) a potential biological control agent for *Mikania micrantha* Kunth. ex H.B.K. (Asteraceae) in India" for the issue of limited field release of the rust pathogen *P. spegazzinii*"at Shastri Bhavan, New Delhi, on 15 June 2005.

"Meeting to monitor the foreign-aided ICAR-CABI collaborative project "Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii*: Implementation phase" at Krishi Bhavan, New Delhi, on 16 June 2005.

"Meeting of the expert committee for assessing and evaluating the impact of the programme on eriophyid mite infestation in coconut" held at PDBC, on 2 August 2005.

"XIV Biocontrol Workers' Group Meeting" at the Sugarcane Breeding Institute, Coimbatore, from 21-22 June 2005.

"Workshop on biocontrol of the weed *Mikania micrantha* in Kerala" organized under the DFID (UK)-funded ICAR-CABI Collaborative project on *Mikania micrantha* by the Kerala Forest Research Institute at Peechi, Kerala on 24 November 2005.

"International Conference: Pathways out of Poverty" organized by the Association of Applied Biologists (AAB) in conjunction with the UK Department for International Development's externally managed resources research programmes at the Homerton College, Cambridge, United Kingdom (UK), 22-23 September 2005.

"Second International Conference on Parthenium Management" jointly organized by the University of Agricultural Sciences (Bangalore) and other organizations at Bangalore, 5-7 December 2005.

"National Meet on Biopesticides in Sericulture-Partnership Avenues", a one-day workshop organized by the Karnataka State Sericulture Research and Development Institute (KSSRDI), Thalaghattapura, Bangalore on 18 January 2006.

Dr. M. Nagesh attended:

Seminar-cum-Workshop on "Capacity building programme for Indian Agricultural Research, Extension and Development Organizations in Globalized Economy" held at NAARM, Hyderabad, from 29-30 April 2005.

"Consultation Meeting on Sericulture Biotechnology" held at CSR&TI, Mysore, from 23-24 May 2005

"Biennial Group Meeting of AICRP (Nematodes)" held at KAU, Vellayani, Thiruvananthapuram, from 7-8 November 2005.

"National Seminar on Biotechnological management of Nematode Pests and Scope of Entomopathogenic Nematodes" held at Sun Agro Biotech Research Centre, Chennai from 21-22 November 2005.

DBT reconstituted "Task Force Meeting on Biopesticides" held at the Habitat Center, New Delhi, from 22-23 August 2005.

"Orientation on Non-Pesticidal Management" at Shri Hanumantharaya Educational and Charitable Society KVK, Yagantipalli,Banaganapalle, from 4-5 February 2006.

Dr. T. Venkatesan attended:

"Seminar-cum-workshop on Capacity Building Programme for Indian Agricultural Research, Extension and Development Organizations in Globalised Economy" held at NAARM, from 19-20 April 2005.

"Third International Training Programme on Molecular Techniques for Crop Improvement" organized by GKVK, Bangalore and Krikhouse Trust, UK, at GKVK, Bangalore, on 19 November 2005.

"Mid-term Review Meeting on Biological Control of Coconut Black-headed Caterpillar, *Opisina arenosella*" organized by the Coconut Development Board at Erode, on 27 August 2005.

Dr. K. Srinivasa Murthy attended:

"Capacity Building in Identification and Management of Mite Pests of Crops" organised by the Department of Entomology, University of Agricultural Sciences, GKVK, Bangalore, from 21 September - 11 October 2005.

"The Open Session on Marker Assisted Selection in Plant Breeding" held at GKVK, UAS, Bangalore, on 19 November 2005, as part of the Third International Training Programme on Molecular Markers for Crop Improvement, Part II : Genetic Mapping" held with the support of Kirkshore Trust, UK and John Innes Centre, Norwich, UK.

"Workshop on Harmonizing Various Research Programmes for Focused Efforts on Development of Successful Management Strategies" held at PDBC, Bangalore, from 4-5 April 2005.

Dr. C. R. Ballal attended:

"Fourteenth Biocontrol Workers' Group Meeting" held at SBI, Coimbatore, from 21-22 June 2005.

"Stakeholders Workshop" organised by NATP for preparing the World Bank assisted NAIP Project held at PDBC, Bangalore, on 6 September 2005.

"The National Convention on Knowledge-Driven Agricultural Development: Management of Change" held at IARI, New Delhi, from 24-26 March 2006.

Visit of Project Director to Centres

The Project Director visited different centres of the All India Coordinated Project to review the work, to understand the difficulties and to resolve problems faced in the implementation of the programmes. The centres visited with dates are given below

1. AICRP centre at PAU, Ludhiana, on 11 April 2005.
2. AICRP centre at College of Agriculture, Pune, on 29 August 2005. Field released the parasitoids at Pune on 30 August 2005.
3. AICRP centre at ANGRAU, Hyderabad, from 8-9 November 2005. Delivered a lecture on BIPM during winter school training at DOR, Hyderabad, on 9 November 2005.
4. AICRP centre at KAU, Thrissur, on 23 November 2005.
5. AICRP centre at AAU, Jorhat, on 26-27 November 2005.
6. AICRP centre at Dr. YSPUH&F, Solan, on 17 January 2006.
7. AICRP centre at KAU, Thrissur on 21 February 2006, and held discussions on production and submission of success story of rice biocontrol.
8. AICRP centres at TNAU and SBI, Coimbatore, from 24-25 February 2006.
9. AICRP centre at AAU, Anand, on 13 March 2006.
10. AICRP centre at SKUAS&T, Srinagar, on 25 March 2006.

16. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, ETC.

Organized at PDBC

- Institute Management Committee meeting: 14 December 2005 & 25 April 2005.
- Interactive Meeting with Zonal coordinators: 28 January 2006
- XIV Biocontrol Workers' Group Meeting: 21 – 23 June 2005
- Institute Research Council Meeting: 6 - 7 April 2005.
- Eleventh Research Advisory Committee meeting: 18 - 19 August 2005.
- Symposium on Biological Control of Pests of Horticultural Crops: New Thrusts.
- Stakeholder Workshop organised by NATP for preparing the worldbank assisted NAIP Project on 6 September 2005 at PDBC, Bangalore.

Celebrated

Anti-Terrorism Day on 21 May 2005

ICAR Foundation Day on 16 July 2005

17. DISTINGUISHED VISITORS

Project Directorate of Biological Control, Bangalore

Dr. Mangala Rai, Secretary, DARE & DG, ICAR, N. Delhi visited PDBC on 1-05-2005

Dr. G. Kalloo, DDG (Hort. & CS) visited PDBC on 20-11-2005

18. PERSONNEL

Project Directorate of Biological Control, Bangalore	
Dr.R.J.Rabindra	Project Director
Dr.P.L.Tandon	Principal Scientist
Dr.K.Narayanan	Principal Scientist
Dr.N.S.Rao	Principal Scientist
Mr.S.R.Biswas	Principal Scientist
Dr.S.S.Hussaini	Principal Scientist
Dr.B.S.Bhumannavar	Principal Scientist
Dr.(Ms.)K.Veena Kumari	Senior Scientist
Dr.Prashanth Mohanraj	Senior Scientist
Dr.B.Ramanujam	Senior Scientist
Dr.N.Bakthavatsalam	Senior Scientist
Dr.S.Ramani	Senior Scientist
Dr.(Ms.)Chandish R.Ballal	Senior Scientist
Dr.M.Nagesh	Senior Scientist
Dr.S.K.Jalali	Senior Scientist
Dr.T.Venkatesan	Senior Scientist
Dr.(Ms.)J.Poorani	Senior Scientist
Dr.P.Sreerama Kumar	Senior Scientist
Dr.K.Srinivasa Murthy	Senior Scientist
Mr.Sunil Joshi	Scientist (SS)
Mr.R.Rangeshwaran	Scientist (SS)
Ms.M.Pratheepa	Scientist (SS)
Central Plantation Crops Research Institute, Regional Station, Kayangulam	
Dr.(Ms.) Chandrika Mohan	Senior Scientist
Central Tobacco Research Institute, Rajahmundry	
Mr.S.Gunneswara Rao	Scientist (SG)
Dr.P.Venkateswarlu	Scientist (SS)
Indian Agricultural Research Institute, New Delhi	
Dr.K.L.Srivastava	Principal Scientist
Indian Institute of Horticultural Research, Bangalore	
Dr.M.Mani	Principal Scientist
Dr.A.Krishnamoorthy	Principal Scientist
Dr. (Ms.) P. N. Ganga Visalakshy	Senior Scientist

Indian Institute of Sugarcane Research, Lucknow

Dr.Arun Baitha	Scientist (SS)

Sugarcane Breeding Institute, Coimbatore

Dr.J.Srikanth	Senior Scientist

Assam Agricultural University, Jorhat

Dr.A.Basit	Principal Scientist
Dr.D.K.Saikia	Senior Scientist

Acharya N.G.Ranga Agricultural University, Hyderabad

Dr.A.Ganeswara Rao	Principal Scientist
Dr.S.J.Rahman	Senior Scientist

Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar

Dr.U.S.Singh	Professor

Gujarat Agricultural University, Anand

Dr.D.N.Yadav	Principal Research Scientist
Dr.B.H.Patel	Associate Research Scientist
Mr.J.J.Jani	Assistant Research Scientist

Kerala Agricultural University, Thrissur

Dr.(Ms.) S.Pathummal Beevi	Associate Professor
Dr.(Ms.) K.R. Lyla	Associate Professor

Mahatma Phule Krishi Vidyapeeth, Pune

Dr.S.A.Ghorpade	Entomologist
Dr.D.S.Pokharkar	Assistant Entomologist

Punjab Agricultural University, Ludhiana

Dr.S.Maninder	Senior Entomologist
Shri. Jagmohan Singh	Assistant Entomologist
Dr. Neelam Joshi	Assistant Microbiologist
Ms.Ramandeep Kaur	Assistant Entomologist
Dr.J.S.Virk	Assistant Entomologist

Sher-e-Kashmir University of Agriculture and Technology, Srinagar

Dr.Abdul Majeed Bhat	Associate Professor

Tamil Nadu Agricultural University, Coimbatore

Dr.R.Balagurunathan	Professor
Dr.N.Sathiah	Associate Professor

Y.S.Parmar University of Horticulture and Forestry, Nauni, Solan

Dr.P.R.Gupta	Senior Entomologist
Dr.Anil Sood	Assistant Entomologist

19. INFRASTRUCTURAL DEVELOPMENT

Equipment

The laboratories were further strengthened with the acquisition of Refrigerated microfuge, dehumidifier (desiccant type), Walk-in chamber, Potter spray tower, Double ended autoclave, Incinerator, Vacuum filtration unit, work station for establishing DNA laboratory, Hand held water activity metre, Vacuum sealing machine.

Library

The library has a collection of 1,820 books, 1288 volumes of journals, 51 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Twelve foreign and fourteen Indian Journals were subscribed. CD-ROM - abstracts upgraded up to February, 2006. New CDs on Crop Protection Compendium 2005 edition was procured

ARIS Cell

Norton Anti-virus software and Mcafee have been upgraded to the latest version. A separate server for Canoma mail has been established to exchange the mails within PDBC. The statistical software Systat version 11.0 and Map Info Professional version 7.0 have been procured and installed in the ARIS Cell.

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.

Land & buildings

The Project Directorate of Biological Control, Bangalore, has leased ten hectares of land in the GKVK campus, University of Agricultural Sciences, Bangalore, to conduct on-farm research and training on biological control of crop pests. An amount of Rs. 172.41 lakhs has been deposited with CPWD, Bangalore for construction of quarantine building with glass house and net house, for addition of first floor on pathology laboratory, for construction of a glass house, for acoustic enclosure, raising of compound wall and for development of the farm (with farm office, stores, shed, field laboratories bore wells, transformer, street lights, glass house, compound wall with gate, barbed wire fencing, road development, water tank and drainage channel).

20. EMPOWERMENT OF WOMEN

During 2005-06, the participation of women in different training programmes was as follows.

I Institutional training programmes conducted at PDBC, Bangalore

"Collection, preservation and identification of insect bioagents" from 01-12-2005 to 07-12-2005

Dr. (Ms.) Rabinder Kaur, Assistant Entomologist, Department of Entomology, Punjab Agricultural University, Ludhiana – 141 004, Punjab

Ms. Ramanadeep Kaur, Assistant Entomologist, Department of Entomology, Punjab Agricultural University, Ludhiana – 141 004

Dr. (Mrs.) Neerja Agrawal, Associate Professor, Department, of Entomology, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur – 208 002, Uttar Pradesh

"New Vistas in Trichogramma Research" from 23-01-2006 to 28-01-2006.

Ms. Pallavi Rabhaji Palande, Junior Research Assistant, Department of Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri,

Ms. A. Anbuselvi, Research scholar, Ethiraj College for Women, Chennai

"Antagonists for Plant disease control" from 20-02-2006 to 25-02-2006

Dr. (Mrs.) Rehumath Niza, T. J., Associate Professor, Department of Plant Pathology, College of Horticulture, Kerala Agricultural University P. O., Vellanikkara, Thrissur-680 656, Kerala

II Tailor-made training programmes

"Mass production and quality control aspects of entomopathogenic nematodes, antagonists and trichogrammatids" from 25-04-2006 to 04-05-2006, Ms. Leepa Abraham, Technical Assistant, POABS Envirotech Pvt. Ltd., Trivandrum

"Production of *Trichogramma* and *Trichoderma*" from 09-01-2006 to 18-01-2006, Ms. Jayashree Hiremath, Agriculture Officer, Parasite laboratory, Bailhongal, Dist. Belgaum

"Mass Production of Bioagents" from 19-05-2005 to 21-05-2005, Ms. A. P. Lucy, Deputy Director & Mrs. P. Sreeja, Agricultural Officer, State Biocontrol Laboratory, Kerala Agricultural University, Thrissur.

"Mass Production of Entomopathogenic Nematodes" from 06-2005 to 31-06-2005