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Biological Control in Latin America and the Caribbean

Its Rich History and Bright Future

EDITED BY JOOP C. VAN LENTEREN, VANDA H.P. BUENO, M. GABRIELA LUNA AND YELITZA C. COLMENAREZ

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and

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Contents

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(1) PDFs of reports and publications in Spanish
(2) A list of areas under biocontrol per crop per country
(3) A list of all organisms mentioned in the book with author names, order, family, common name and chapter in which the organism is mentioned
(4) List of countries with classical biocontrol introductions
(5) List of introductions for classical biocontrol per decade
(6) List of addenda and corrections

These resources can be found at: https://www.cabi.org/openresources/42430

About the Editors

The editors of this book all have many years of experience with biological control in the Latin American region.

Vanda H.P. Bueno is Full Professor of Biological Control of Pests at the Federal University of Lavras, Minas Gerais, Brazil. She was initially working on natural enemies of forest pests and pests in coffee plantations, but subsequently switched to augmentative biocontrol in protected cultures. She was a postdoctoral fellow at UC Berkeley, USA. Currently, she studies Neotropical predatory mirids for pests such as *Tuta absoluta* and whitefly in tomato. She has supervised many Brazilian, Colombian, Cuban and Dutch BSc, MSc and PhD students, published 150 peer-reviewed papers and 19 book chapters and produced two editions of the book *Biological Control of Pests: Mass Production and Quality Control*. She is an active member of the Neotropical Regional Section of IOBC (IOBC-NTRS) where her previous roles were president and treasurer; she is now vice-president of IOBC-Global.

Yelitza C. Colmenarez is a specialist in sustainable production – she is heavily involved in biological control and plant protection techniques, with more than 15 years of experience working with multidisciplinary teams, developing international cooperation projects and establishing sustainable production programmes in Latin America and the Caribbean. She has published 15 peer-reviewed papers and ten book chapters, edited a book on *Biological Control of Plant Diseases in Latin America and the Caribbean*, developed a *Field Guide for Identification of Natural Enemies* and conducted 35 international cooperation projects in Latin America and the Caribbean. Currently, she is the CABI Latin America Centre Director and also works as past president and advisor of IOBC-NTRS.

María Gabriela Luna is a researcher at CEPAVE (CONICET-UNLP-asociado CIC-BA), La Plata, Argentina, and professor at UNLP and UNSAdA, Argentina. Her interest in agroecology, entomology and biological control led to studies of parasitoid insects and to evaluating their potential as natural enemies of pests in field and protected crops. She was a postdoctoral fellow at UC Irvine, USA. Currently, she is involved in projects to develop augmentative biological control for *Tuta absoluta* by means of parasitoid species. She has supervised ten MSc and PhD students and published over 30 peer-reviewed papers and two book chapters. She acts in Academic and Counseling committees at UNLP, UNSAdA, CONICET and IOBC-NTRS. She was the secretary of the Executive Committee of IOBC/NTRS from 2010 to 2018.

Joop C. van Lenteren is Emeritus Professor of Entomology at Wageningen University, The Netherlands. He started working on biocontrol of whiteflies and other pests in greenhouses in the 1970s, which later resulted in widely applied IPM programmes comprising many species of natural enemies and microbial control agents for all major pests and several diseases in protected cultivation. He became involved in Latin American biocontrol when he represented Wageningen University in international collaboration programmes starting in the 1990s. He now works on the development of evaluation criteria for selection of promising natural enemies and on Neotropical mirids. He has supervised 260 MSc and 84 PhD students from Europe, Asia, Africa, North and South America. He has published more than 200 peer-reviewed papers and edited several books on IPM and biocontrol. From 2000 to 2016, he fulfilled several different functions in the Executive Committee of IOBC-Global, as well as in the European section of IOBC (IOBC-WPRS).

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Foreword

Although overviews of the history and the current state of affairs in biological control have been published for several world regions, such as Europe, North America and Australia, this information has been lacking for Latin America and the Caribbean. Two of the editors of the current book – Bueno and Van Lenteren – wrote a review in 2003 with the title 'Augmentative Biological Control of Arthropods in Latin America' (*BioControl* 48, 123–139), and the last lines in this paper were: 'It has taken us a lot of time to obtain data on the use of biological control in Latin America, and we are convinced that this survey is still not complete. We encourage readers to send us up to date information, so we can provide a more reliable overview in the near future.' As a result of this request, we received a good amount of reactions, and we began to understand that there was a large quantity of information in Spanish and Portuguese publications and reports. However, this information was either hard to access, or could not be understood easily by an international readership. We also realized that the amount of material was too large and too interesting for a simple update of the above-mentioned review. Clearly, producing an entirely new book would be a better solution. Ideas for an English language publication on biocontrol in Latin America and the Caribbean were discussed with members of the Executive Committee of NeoTropical Regional Section of the International Organisation for Biological Control (IOBC-NTRS), and potential authors in the region were contacted. By the end of 2016, we had succeeded in obtaining authors for most countries with significant biocontrol activities and we could start with writing and editing the country-specific chapters.

Why do we think it important to have this information available in English? First of all, the large amount of historical knowledge about biocontrol in this region deserves the attention of those working in biocontrol elsewhere in the world. We document both successes and failures. Facts about successes in certain regions may help researchers elsewhere in finding candidate natural enemies for the same or similar pests in their area. Furthermore, the lists of biocontrol agents found in a certain country or region of Latin America and the Caribbean which we provide in this book might help to facilitate Access and Benefit Sharing procedures, compulsory since the ratification of the Nagoya Protocol in 2014 (see Chapter 1 for details). We are also convinced that knowledge about projects that failed is essential to prevent making the same mistakes in the future.

Secondly, by providing an extensive overview of the current situation in biocontrol for many Latin American and Caribbean countries, we aim not only to show what is happening in this region, but also to help in networking and collaboration between regions with similar pest problems.

Thirdly, during the data collection phase for the book, we were astonished by the amount of practical biocontrol applied in this region, which was often undocumented or not easily available.

Preface

I am absolutely delighted that this volume focusing on biological control in Latin America and the Caribbean has been put together. It is a very important piece of scholarship that highlights an inspiring amount and breadth of work that has been going on in this region over the past century. The editors include luminaries in the area of biological control in Latin America and internationally, and they have gone to great lengths to provide a comprehensive treatment of biological control in countries ranging from Mexico and the Caribbean Islands to the tip of Tierra del Fuego – more than 30 countries are represented in all! What is so important about this compendium is that it brings to light information that was previously either inaccessible or very difficult to find. In our current age of instant gratification I worry that many scientists would not do the work to dig up information even in the 'difficult to find' category and so this volume is all the more appreciated.

Biological control remains the best way to combat many invasive pests, diseases and weeds, and for ensuring a healthy and sustainable food supply. With the recent improvements in safety protocols and commercial production of effective agents, there is really no reason for biological control not to expand to meet growing problems in invasive species and food security worldwide. Biological control is particularly important in regions like Latin America, where some farmers cannot afford pesticides in the first place, and where some of the compounds that are available pose very serious risks to human and environmental health. Latin America also contains some of the world's most celebrated and pristine natural areas and is the region with the highest biodiversity in the world, some of which is under threat from invasive species. The capacity to engage these problems on a regional basis is there but needs to be nurtured and improved. This book is an important part of this process, as it not only documents a rich history of biological control in the region but also points a way forward to a Latin America under diminished pressure of invasive species and pesticides.

George E. Heimpel

President, International Organisation for Biological Control (IOBC) Global,
and Professor of Entomology, University of Minnesota, USA.

Dedication and Acknowledgements

The editors would like to dedicate this book first of all to the pioneers of biological control in this region. The first pioneers, the indigenous peoples of the Americas, considered the majority of insects as non-harmful, and reduced the impact of harmful species by inter- and multi-cropping, periods of fallow, use of optimal production sites, and even a form of field selection of resistant cultivars. Farmers recognized the contribution to pest reduction by spiders, aquatic nymphs of dragon flies, lizards, snakes, squirrels, weasels and skunks. In Nicaragua, for example, ancient people recognized the value and abundance of insects as natural enemies of pests, and coined them *náhuatl* (Dávila, 1992: *Glosario de nombres náhuatl de plantas, pájaros y algunas otras especies, con descripción de su etimología y comentarios del autor* (*Glossary of náhuatl names for plants, birds and other species, with etymological descriptions and commentaries from the author*). Fondo Editorial Centro de Investigación de la Realidad de América Latina (CIRA). Managua, Nicaragua, 47pp.)

Many of the second group of pioneers, i.e. those who started using biocontrol at the beginning of the 20th century, are mentioned in the country-specific chapters. Although native biocontrol agents were often used, in many other cases natural enemies were imported from other regions in the world, either because the crops with their pests originated from these regions, or because information was available about the success rate of certain natural enemies.

We would also like to dedicate the book to those who were able to persevere successfully with earlier developed biocontrol projects, or even to develop and implement new applications after 1945, when the use of chemical control increased dramatically. This was a difficult period for biocontrol in most Latin American countries, and many effective projects were either terminated due to market pressure by the pesticide industry, or because they could no longer function due to negative side effects of synthetic chemical pesticides.

The book is also dedicated to everyone who is currently studying, teaching and practising biological control in Latin America and the Caribbean. Although biocontrol is now applied widely in this region, researchers and producers of biocontrol agents continue to be confronted with the overwhelming dominance of the chemical pesticide industry. We know it requires an enormous amount of stamina to keep convincing farmers, policy makers and governments that biocontrol is the most sustainable, economic and safest way to reduce pests, diseases and weeds!

Finally, we dedicate the book to the next generation with an interest in the production of sufficient and healthy food, and in restoring biodiversity in this region. We, the editors, can assure you that the study of biocontrol, which actually is an extremely interesting combination of applied microbiology, behaviour, ecology and environmental sciences, is always fascinating and very rewarding.

Glossary

Acronym	Details
ABC	augmentative biological control
ABCBio	Brazilian Association of Biocontrol Companies
ABRAF	Associação Brasileira de Produtores de Florestas Plantadas
ABS	Access and Benefit Sharing [Nagoya Protocol]
ACMNPV	*Autographa californica* multiple nucleopolyhedrovirus
ACP	Asian citrus psyllid
ADEXVO	Asociación Dominica de Exportadores de Vegetales Orientales
AgMNPV	*Anticarsia gemmatilis* multiple nucleopolyhedrovirus
AgNPV	*Anticarsia gemmatilis* nucleopolyhedrovirus
AGROCALIDAD	Ecuadorian Agency to assure quality in Agriculture
Agrosavia	Corporation for Agricultural Research [Colombia] (formerly Corpoica)
ALAM	Asociación Latinoamericano de Microbiología
ALF	Asociación Latinoamericana de Fitopalogía
AMID	Agricultural Marketing Information Division
ANACAFÉ	Asociación Nacional del Café [Guatemala]
ANAO	Asociación Nacional de Agricultura Orgánica [National Association of Organic Agriculture]
ANAPO	Asociación de Productores de Oleaginosas y Trigo
ANCA	National Cotton Association [Venezuela]
ANCUPA	Association of Oil Palm Growers
ANECAFE	Association of Coffee Exporters of Ecuador
ANII	National Agency for Research and Innovation
APCB	Asociación Peruana de Control Biológica
APHIS	Animal and Plant Health Inspection Service [USDA]
APM	agroecological pest management
Ascolflores	Asociación Colombiana de Exportadores de Flores
asl	above sea level
BCL	Biological Control Laboratory
BIOESA	Biológicos Ecuatorianos S.A.
BRGM	Banco de Recursos Genéticos Microbianos [Microbial Genetic Resources Bank]
Bt	*Bacillus thuringiensis*
BYDV	barley yellow dwarf virus

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Acronym	Details
CABI	Centre for Agriculture and Biosciences International
CARDI	Caribbean Agricultural Research and Development Institute
CARICOM	Caribbean Community
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza [Tropical Agriculture Research and Higher Education Center]
CBB	coffee berry borer
CBBC	Commonwealth Bureau of Biological Control
CBC	classical biological control
CBD	Convention on Biological Diversity [Rio]
CCBBM	Center for Biological Control and Molecular Biology
CCBCA	Centro para el Control Biológico en Centroamérica
CChRGM	Collección Chilena de Recursos Genéticos Microbianos [Chilean Collection of Microbial Genetic Resources]
CCIPA	Comité de Control Integrado de Plagas del Algodonero
CDF	Charles Darwin Foundation
CEA	Centro de Entomoligía Aplicada [Applied Entomology Center]
CEA	Consejo Estatal del Azucar [State Sugar Council]
CEAZA	Centro de Estudios Avanzados en Zonas Arida [Center for Advanced Studies in Arid Zones]
CEBIOF	Center for Forest Bioservices
CECTEC	Centro de Educación, Capacitación y Tecnología Campesina [Center of Education, Training and Peasant Technology]
CEDAF	Centro de Desarrollo Agropecuario y Forestal [Center for Agricultural and Forestry Development]
CEMUBIO	Center for Reproduction of Biocontrol Agents
CENA	Centro de Energia Nuclear na Agricultura
CENAPROVE	Centro Nacional de Protección Vegetal [National Center for Plant Protection]
CENETROP	Centro Nacional de Enfermedades Tropicales
CENIAP	National Center for Agricultural Research
Cenicafé	National Coffee Research Center
CENSA	Centro Nacional de Sanidad Agropecuaria
CENTA	Centro de Tecnologías Agrícolas / Centro Nacional de Tecnologia Agropecuaria
CEPAVE	Centro de Estudios Parasitológicos y de Vectores
CEQIS	Center for Excellence in Quarantine and Invasive Species
CESDA	Centro Sur de Desarrollo Agropecuarios
CFF	carambola fruit fly
CFS	Colombian fluted scale
CGA	Citrus Growers Association
CGIAR	Consortium of International Agricultural Research Centers
CIA	Central Intelligence Agency
CIAC	Central Research Center of IDIAP
CIAT	International Center for Tropical Agriculture
CIB	Coffee Industry Board
CIBC	Commonwealth Institute for Biological Control
CICIU	Centro de Introducción y Cría des Insectos Utiles [Center for Introduction and Rearing of Useful Insects]
CIMCA	Centre for Research and Improvement of Sugarcane
CIMIC	Center for Microbiological Research
CIMMYT	International Maize and Wheat Improvement Center
CINCAE	Sugar Cane Research Center
CIP	International Potato Center
CIPROC	Crop Protection Research Center
CIRA	Centro de Investigación de la Realidad de América Latina
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement

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Acronym	Details
CIRCB	Centro de Investigación Reproducción Control Biológico
CIRPON	Centro de Investigaciónes sobre Regulación de Poblaciones de Organismes Nacivos
CITTCA	Centro de Investigación y Transferencion de Tecnológia para la Caña de Azúcar [Center for Research and Technology Transfer for Sugar Cane]
CNRCB	Centro Nacional de Referencia de Control Biologico
CNSV	Centro Nacional de Sanidad Vegetal
CODOCAFÉ	Consejo Dominicano del Café
CONAF	Corporación Nacional Forestal [National Forerst Corporation]
CONIAF	Consejo Nacional de Investigaciones Agropecuaria y Forestales [National Council of Agriculture and Forestry Research]
CONICET	National Council of Scientific and Technical Research
CONQUITO	Economy Promotion Agency, Quito Municipality
ConsBC	conservation biological control
CORBANA	National Banana Corporation
CoSAVE	Comité de Sanidad Vegetal [Plant Health Committee]
CPF	Forestry Pest Control Company
CpGV	*Cydia pomonella* granulovirus
CPHST	Center for Plant Health Science and Technology
CRE	Centros Reproductores de Entomófagos
CREE	Entomophagous and Entomopathogens Mass Rearing Centers
CREI	Citrus Research and Education Institute
CSIRO	Commonwealth Scientific and Industrial Research Organization
CTCB	Biological Control Technological Center
CTV	citrus tristeza (clostero)virus
CURLA	Regional University Center of the Atlantic Coast
CVA	Venezuelan Agrarian Corporation
DAJ	Department of Agriculture, Jamaica
DANE	Departamento Administrativo Nacional de Estadística
DFP	Departmento de Fitopatologia
DGSA	General Directorate of Agricultural Services
DGSV	Dirrección General de Sanidad Vegetal [General Directorate of Plant Health]
DIECA	División de Investigación en Caña de Azúcar [Sugar Cane Research and Extension Division]
DOF	Diario Oficial de la Federación [Official Journal of the Federation]
DOMEX	Dominica Export
DPNG	Dirección del Parque Nacional Galápagos
DPV	Departamento de Protección Vegetal
DSV	Department of Plant Health
ECI	Exportando Calidad e Inocuidad
EF1α1	elongation factor 1α1
EMATER-PR	Instituto Paranaense de Assistência Técnica e Extensão Rural
EMBRAPA / Embrapa	Empresa Brasileira de Pesquisa Agropecuária
ENA	Encuesta Nacional Agropecuaria [National Agricultural Survey]
ENEE	National Electrical Company
EPA	Environmental Protection Agency (US)
EPF	entomopathogenic fungi
EPN	entomopathogenic nematodes
ERPE	Escuelas Radiofónicas Populares del Ecuador
ESALQ	Escola Superior de Agricultura 'Luiz de Queiroz'
ESPAC	Encuesta de Superficcie y Producción Agropecuaria Continua
ESPOCH	Polytechnic University of Chimborazo Province
ETPP	Territorial Stations of Plant Health

Continued

Acronym	Details
FAO	Food and Agriculture Organization of the United Nations
FAPESP	São Paulo Research Foundation
FBC	fortuitous biocontrol
FCA-UNA	Facultad de Ciencias Agrarias, Universidad Nacional de Asunción [Faculty of Agricultural Sciences]
FCQ-UNDA	Facultad de Ciencias Químicas, Universidad Nacional de Asunción [Faculty of Chemical Sciences]
FDA	Fundacion de Desarrollo Agropecuario [Center for Agricultural Development]
FEPAF	Foundation for Agricultural and Forestry Studies and Research
FFS	Farmer Field Schools
FHTET	Forest Health Technology Enterprise Team
FIA	Fundación para la Innovación Agraria
FINTRAC / Fintrac	(private US-based non-governmental organization)
FONAIAP	National Agricultural Research Fund (currently INIA)
FONDAFA	Development Fund for Agriculture, Fishing, Forestry and Related Activities
FONDEF	Fondo de Desarrollo Cientifico y Tecnológico [Scientific and Technological Development Fund]
FREDON	Fédérations Régionale de Défense contre les Organismes Nursibles [Regional Federation of Protection Against Damaging Organisms]
FUEDEI	Fundación para el Estudio de Especies Invasivas
FUNCEMA	National Resources Unit for Control of Sirex Wood Wasp
FUNDACAÑA	Sugar Foundation for Development, Productivity and Research
FUNDAR	(an Ecuador NGO)
FUNICA	Fundación para el Desarrollo Tecnológico Agropecuaria, Forestal de Nicaragua
FUSAGRI	Fundación Servicio para el Agricultor
GAP	Good Agricultural Practices
GAR	Government of the Argentine Republic
GBIF	Global Biodiversity Information Facility
GRDB	Guyana Rice Development Board
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit [German Cooperation Agency] [Sociedad Alamana de Cooperación Técnica]
HLB	huanglongbing [lit. yellow dragon disease] = citrus greening
HzSNPV	*Helicoverpa zea* nucleopolyhedrovirus
IAEA	International Atomic Energy Agency
IANAS	Inter-American Network of Academies of Sciences
IASA	Andean Institute of Agriculture
IBA	Indústria Brasileira de árvores
IBGE	Institute Brasileiro de Geografia e Estatistica
IBSP	Instituto Biológica São Paulo
ICA	Instituto Colombiano Agropecuario [Colombian Agricultural Institute]
ICAFE	Instituto del Café de Costa Rica
ICDF	International Cooperation Development Fund
ICIDCA	Institute de Investigaciones de Derivados de la Caña de Azúcar
IDA	International Depository Authority
IDIAF	Instituto Dominicano de Investigaciones Agropecuarias y Forestales
IDIAP	Instituto de Investigación Agropecuaria de Panamá
IE	Institute of Ecology
IFAD	International Fund for Agricultural Development
IFPA	Institute for the Promotion of Sugar Production
IIBC	International Institute of Biological Control
IICA	Instituto Interamericano de Cooperación para la Agricultura [Inter-American Institute for Cooperation on Agriculture]
IITA	International Institute of Tropical Agriculture
IMO	Institute of Marketology
IMTA	Mexican Institute of Water Technology

Continued

Acronym	Details
MINAG	Ministry of Agriculture
MINAGRI	Ministerio de Agricultura y Riego
Minagri	Ministry of Agribusiness [Argentina]
MIPH	Manejo Integrado de Plagas en Honduras
MoAF	Ministry of Agriculture and Fisheries
MOSCAMED / Moscamed	mosca de la fruta del Mediterráneo [Mediterranean fruit fly] [= medfly, *C. capitata*]
MRL	maximum residue level
NAREI	National Agricultural Research and Extension Institute
NC	natural control
NGO	non-governmental organization
NPV	nuclear polyhedrosis virus
NRI	Natural Resources Institute
OCM	Organización Mundial de Comercío [= World Trade Organization, WTO]
ODA	Overseas Development Agency
ODEPA	Oficina de Estudios y Politicas Agrarias
OEA	Organización de los Estados Americanos [Organization of American States]
OECD	Organization for Economic Co-operation and Development
OIRSA	Organismo Internacional Regional de Sanidad Agropecuaria [International Regional Organization for Plant Protection and Animal Health]
PIOJ	Planning Institute of Jamaica
PLANUSA	Plan International USA
PNAO	Programa Nacional de Agricultura Organica [National Program of Organic Agriculture]
PNCB	National Program of Biological Control
PNCVM PIVCVM	National Program for Control of Wood Wasp
PNMIP	Programa Nacional de Manejo Integrado de Plagas
PNV	polyhedrosis nuclear virus – *see* NPV
PRECODEPA	Programa Regional Cooperative de Papa
PROBIOMA	Productivity Biosphere and Environment
PROBIOTEC	Center for Research, Diagnosis and Production of Biocontrol Agents for Control of Pests and Diseases
PROCOBI	National Program for Biological Control
PRODESA	Development Program of Agricultural Health
PROIMI	Pilot Plant of Industrial Microbiological Processes
PROINPA	Fundación para la Promoción e Investigación de Productos Andinos [Potato Research Project]
PROMECAFE	Regional Cooperative Program for Technological Development and Modernization of the Coffee Industry
PROMIB	Programa de Manejo Integrado de la Broca del Cafe
PROMSA	Program for Modernization of Agricultural Services
PROTEF / IPEF	Programa de Proteção Florestal / Instituto de Pesquisas e Estudos Florestais
RCC	Regional Research Center
REDCAHOR	Red Colaborative de Investigación, Desarrollo de las Hortalizos para América Central [Collaborative Vegetable Research and Development Network]
RKN	root-knot nematode
SAC	Sociedad de Agricoltores de Colombia
SAG	Servicio Agricola y Ganadero
SAGARPA	Secretaría de Agricultura y Desarrollo Rural [Ministry of Agriculture, Livestock, Rural Development, Fishers and Food]
SASA	Autonomous Service of Agricultural Health
SCB	Subdirección de Control Biológica
SCBD	Secretariat of the Convention on Biological Diversity
SEA	Secretariía de Estado de Agricultura

Continued

Acronym	Details
SEB	Sociedad Entomológica do Brasil [Entomological Society of Brazil]
SENASA	Servicio Nacional de Sanidad y Calidad Agroalimentaria
SENASAG	National Service of Agricultural Health and Food Safety
SENASICA	Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria [National Service of Health, Safety and Agrifood Quality]
SENAVE	Servicio Nacional de Calidad y Sanidad Vegetal y de Semillas
SeNPV	*Spodoptera exigua* nucleopolyhedrovirus
SERVBIO	Biological Control Service Company
SESA	Ecuadorian Service for Agricultural Health
SFE	Servicio Fitosanitario del Estado
SfMNPV	*Spodoptera frugiperda* nucleopolyhedrovirus
SIAP	Servicio de Información Agroalimentario y Pesquera
SICGAL	Galapagos Inspection and Quarantine System
Siconbiol	Symposium of Biological Control
SINAGAP	Sistema de Información Nacional de Agricultura, Ganadería, Acuacultura y Pesca
SIRDI	Sugar Industry Research and Development Institute
SIT	sterile insect technology / sterile insect technique
SMBC	Sociedad Mexicana de Control Biológico
SNI – SENACYT	Sistema Nacional de Investigación – Secretaría Nacional de Ciencia, Technlogía e Innovación
SPF	Forestry Producers Association
SRL	Sociedad de responsabilidad limitada [equiv. of 'limited liability company']
SSF	solid-state fermentation
TL50	lethal time
TnNPV	*Trichoplusia ni* nucleopolyhedrovirus
UAGRM	Autonomous University Gabriel Rene Moreno
UASD	Universidad Autónoma de Santo Domingo
UAV	unmanned aerial vehicle [= drone]
UCLA	Universidad Centro Occidental 'Lisandro Alvarado'
UCV	Central University of Venezuela
UdelaR	Universidad de la Republíca [Republic University of Uruguay]
UENF	Universidade Estadual do Norte Fluminense Darcy Ribeiro
UFV	Universidade Federal de Viçosa
UNA	Universidad Nacional Agraria
UNAN	Universidad Nacional Autónoma de Nicaragua
UNDP	United Nations Development Programme
UNESP-FCA	Universidad Estadual Paulista – Faculdade de Ciéncias Agronómicos
UN-IAEA	see IAEA
UNPHU	Universidad Nacional Pedro Henríquez Ureña
UPAVE	Venezuelan Sugarcane Producers Association
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USDA ARS	USDA Agriculture Research Service
USDA-NRCS	USDA National Resource Conservation Service
USP	Universidad de São Paulo
VG	granulosis virus
VIFINEX	Vigilancia Fitosanitaria en Cultivos de Exportación no Tradicionales
VPNAg	see AgNPV
WDF	water-diluted granules
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WREP	Whitefly Research and Extension Project

23 Biological Control in Panama

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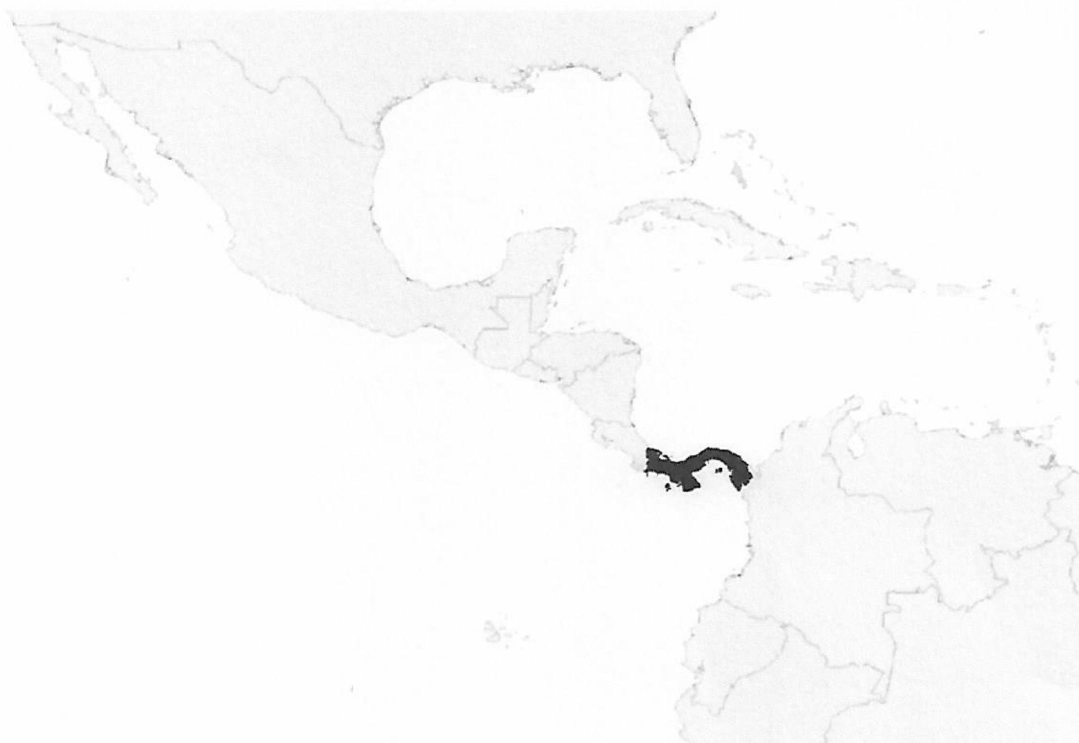

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Abstract

The first activity in biological control in Panama concerned import and release of a parasitoid of citrus blackfly in 1931. Later, the development of biocontrol programmes was targeted mainly against pests in sugarcane, vegetables, cantaloupes, watermelons, coffee and rice. In the 1970s, the releases of *Cotesia flavipes* and *Paratheresia claripalpis* for the control of *Diatraea saccharalis* guaranteed the cost effectiveness of the crop. Subsequently, *Diadegma semiclausum*, *Cotesia plutellae* and *Microplitis plutellae* were imported in the 1990s for biocontrol of *Plutella xylostella* in cruciferous crops. This was followed in the 2000s by the introduction of *Prorops nasuta* and *Phymastichus coffea* for the management of *Hyphotenemus hampei*. Prospecting programmes were executed in Panama to collect and identify natural enemies of, among others, whiteflies, leaf miners, thrips, mites and rice stink bug. Also a large number of entomopathogenic fungal strains were collected and identified. Several of the natural enemies and entomopathogens that were found to be promising as biocontrol agents are now mass produced and tested in the field. Ongoing work on artificial diets for mass rearing of pests that serve as hosts/prey for natural enemies is expected to result in cheaper production of biocontrol agents. Recently a conservation biocontrol programme was started for control of the rice stink bug by studying how weeds in and near rice fields can attract and stimulate populations of parasitoids of the stink bug.

23.1 Introduction

Panama has an estimated population of slightly more than 3,750,000 (July 2018) and its main agricultural products are bananas, rice, maize, coffee, sugarcane, vegetables, livestock and shrimp (CIA, 2019). According to Zachrisson *et al.* (2017, pp. 455 and 463):

> The country has an area of 75,845.072 km² ... Agricultural land covers 30.4% of the country's total area ... Panama boasts a variety of agricultural, livestock, fishery and aquaculture production systems, the most important being rainfed and irrigated rice, bovine milk and meat, swine and avian production and wild-caught fish ... Panama's forest resources are characterized by mature forest cover, intervened and secondary forests, which accounted for 61.9% of the land area in 2014.

23.2 History of Biological Control in Panama

23.2.1 Period 1880–1969

Investigations into biological control in Panama began in 1931 and were focused on managing citrus blackfly *Aleurocanthus woglumi* Ashby, with releases of the parasitoid *Eretmocerus serius* Silvestri (Rodríguez and Arredondo, 2007) in citrus groves from 1931 to 1943 (Table 23.1). This parasitoid was studied also by H.D. Smith, a US Department of Agriculture (USDA) entomologist based in Panama in 1943, who reared *E. serius* (Arredondo-Bernal and Rodríguez-del-Bosque, 2008).

23.2.2 Period 1970 –2000

During this entire period, inundative releases of *Cotesia flavipes* Cameron were made in sugarcane, resulting in high parasitism rates of *Diatraea saccharalis* Fabricius, but not of *Diatraea tabernella* (Dyar). The economic impact of *D. tabernella* exceeded that reported for *D. saccharalis* (López, 1995), but lack of information about natural enemies made biocontrol of this borer difficult. Later, integrated pest management (IPM) in sugarcane plantations made production profitable and the biocontrol component consisting of simultaneous releases of *Paratheresia claripalpis* Wulp and *C. flavipes* resulted in improved biocontrol of *Diatraea* sp.: a cumulative number of 5,721,180 of these parasitoids were released on a cumulative cultivated area of 292,930 m² (Rodríguez *et al.*, 2004).

In the early 1990s, *Bemisia tabaci* (Gennadius) transmitted *Begomovirus* to Cucurbitaceae and Solanaceae, in particular to melon, watermelon and tomato. Conservation biocontrol was studied as a management option for *B. tabaci*. The following natural enemies were found in the locality of Los Santos, Panama: *Encarsia* sp. *Eretmocerus* sp. *Cycloneda sanguinea* L., *Hippodamia convergens* Guérin-Méneville, *Coleomegilla maculate* De Geer, *Scymnus* sp., *Chrysopa* sp. and *Polistes panamensis* L. (Zachrisson, 1992) (Table 23.1). Other species of parasitoids were subsequently identified, among which *Encarsia pergandiella* Howard, *Signiphora* sp. and *Amitus* sp. were identified for the first time in Panama (González *et al.*, 2009). *B. tabaci* on tomato in Los Santos showed rates of parasitism between 20.4% and 14.8%.

Table 23.1. Chronology of activities related to biological pest control in Panama.

Year	Activity	Biocontrol agent	Pest	Reference
1931	Introduction from Cuba	*Eretmocerus serius*	*Alerocanthus woglumi*	Altieri *et al.*, 1989
1938/43	First and second export to Mexico	*E. serius*	*A. woglumi*	Rodríguez and Arredondo, 2007
1991	Parasitoids identified in Cerro Punta, Chiriquí	*Diglyphus* sp., *Chysocharis* sp., *Oenonogastra* sp., *Halticoptera* sp.	*Liriomyza huidobrensis*	González, 1991; Morales *et al.*, 1994
1992	Parasitoids and predators identified in crops and weeds in the region of Azuero	*Encarsia* sp., *Eretmocerus* sp., *Coleomegilla maculata*, *Chrysopa* sp.	*Bemisia tabaci*	Zachrisson, 1992
1999	Multiplication of parasitoids	*Microplitis plutellae*, *Cotesia plutellae*	*Plutella xyllostella*	REDCAHOR, 2000
1999	Introduction from Nicaragua	*Diadegma semiclausum*	*P. xylostella*	REDCAHOR, 2000
2000	Multiplication/release/evaluation of parasitism	*D. semiclausum*	*P. xylostella*	Abrego and Polanco, 2001
2002	Identification of parasitoids in rice	*Telenomus podisi*, *Trissolcus basalis*	*Oebalus insularis*	Zachrisson, 2009
2003	Identification of parasitoids in melon	*Trichogramma* sp., *Conura* sp.	*Diaphania hyalinata*, *D. nitidalis*	Barba and Korytkowskl, 2004
2004	Inventory of predatory mites in rice	*Proprioseiopsis* sp.	*Steneotarsonemus spinki*	Camargo *et al.*, 2009
2005	Parasitism of pest in rice	*Telenomus rowani*	*Rupela albinella*	Zachrisson, 2009
2006	Predators identified in Azuero	*Orius insidiosus*, *O.* spp.	*Thrips palmi*	Barba, 2007
2006	Import from Colombia	*Prorops nasuta*, *Phymastichus coffea*	*Hypothenemus hampei*	Pérez, 2006
2006	Use of entomopathogenic fungi	*Beauveria bassiana*	*H. hampei*	Pérez, 2006
2007	Identification of native entomopathogens	*Beauveria* sp.	*H. hampei*	Morales *et al.*, 2009
2007	Parasitoid releases on farms	*Cephalomia stephanoderis*	*H. hampei*	Pérez, 2006
2007	Parasitoids identified in tomato and pepper	*Eretmocerus* sp., *Amitus* sp., *Signiphora* sp., *Encarsia quaintancei*, *E. bimaculata*, *E. pergandiella*, *E. hispida*, *E. porteri*, *E. citrella*, *E. nigricephala*	*B. tabaci*, *Trialeurodes vaporariorum*	González *et al.*, 2009
2007	Identification of native entomopathogens	*M. anisopliae*, *B. bassiana*, *Paecilomyces* sp.	*Cyrtomenus bergi*	Barba *et al.*, 2009a
2009	Effect of entomopathogens on pest and natural enemy	*B. bassiana*, *M. anisopliae*	*Gynaikothrips* sp.	Hirano and Barba, 2009a
2009	Efficacy of entomopathogen	*M. anisopliae*	*D. hyalinata*	Hirano and Barba, 2009b

Continued

Table 23.1. Continued.

Year	Activity	Biocontrol agent	Pest	Reference
2008	Evaluation of predation capacity	*O. insidiosus*	*T. palmi*	Hirano, 2009; Rivera, 2009
2008	Efficacy of native of entomopathogenic fungi	*B. bassiana*, *M. anisopliae*	*Anthonomus eugenii*	Barba *et al.*, 2009b; Hirano and Barba, 2009b
2009	74 strains of entomopathogenic fungi identified	Entomopathogenic fungi	Insect pests	Barba, 2010
2010	Identification of predatory mites	*Neoseiulus baraki*, *N. barabesis*, *Hypoaspis* sp., *Pseudoparasitus* sp.	*Steneotarsonemus spinki*	Quirós and Rodríguez, 2010
2013	Isolation, identification and characterization of 54 native strains of entomopathogens	*Beauveria* sp., *M. anisopliae*, *Paecilomyces* sp.	Insect pests	Gutiérrez and Vega, 2013
2015	Characterization of native isolate "rs006"	*Isaria javanica*	*H. hampei*	González *et al.*, 2015
2015	Pathogenicity/virulence of native isolate	*Isaria* spp.	*H. hampei*	Lezcano *et al.*, 2015

The diamondback moth *Plutella xylostella* L. caused serious damage on broccoli (*Brassica oleracea* L. var. *Italica*) and cauliflower (*Brassica oleracea* L. var. *Botrytis*) in Cerro Punta and Boquete, Chiriquí in Panama. Therefore, as part of an initiative by the Collaborative Vegetable Research and Development Network (Red Colaborativa de Investigación y Desarrollo de Hortalizas para América Central) (REDCAHOR), several species of parasitoids were introduced in 1998, among them *Diadegma semiclausum* Hellen, *Cotesia plutellae* Kurdjumov and *Microplitis plutellae* Muesbeck (REDCAHOR, 2000). International operations facilitated the importation of these species from Nicaragua, followed by their multiplication in the laboratory. The parasitism rate of *P. xylostella* was 78.8% under laboratory conditions and 33.1% in the field.

Severe attacks by the polyphagous leaf miner *Liriomyza huidobrensis* Blanchard on various horticultural crops were reported in Cerro Punta, Chiriqui in early 1990 (Morales *et al.*, 1994). Native parasitoids were collected in Cerro Punta and Boquete, Chiriquí, indicating the presence of species of four genera: *Diglyphus* Walker, *Chrysocharis* Foster, *Oenonogastra* Ashmead and *Halticoptera* Spinola, including *Oenonogastra microrhopalae* Ashmead, *Diglyphus isaea* Walker, *Opius dimidiatus* Ashmead and *D. websteri* Crawford, as well as other parasitoids and predators (González, 1991) (Table 23.1).

23.3 Current Biological Control Situation in Panama

Diaphania hyalinata L. and *Diaphania nitidalis* Stoll are considered key pests of the family Cucurbitaceae, including melon, watermelon and squash. Both species have similar habits and occur on cultivated and wild plants. With the support of the International Regional Agency for Agricultural Health through the Vigilancia Fitosanitaria en Cultivos de Exportación no Tradicionales (VIFINEX) project and the Central American Master's Program in Entomology of the University of Panama, the population dynamics of *D. hyalinata* and *D. nitidalis* were determined in plots planted with melon, watermelon and squash. Several parasitoid taxa were identified, including *Trichogramma* sp., *Apanteles* sp., *Conura* sp., *Copidosoma truncatellum* Dalman, *Lespesia* sp. and *Drino* sp. (Korytkowski, 2003). Barba and Korytkowski (2004) reported a 35.0% egg parasitism rate by *Trichogramma* sp. and a larval parasitism rate of 37.5% by *Stantonia* sp. and *Conura* sp. However, the impact of native natural enemies on these species is variable.

Discovery of the coffee berry borer in 2005 at the Bajo Cerrón farm in Río Sereno, Chiriquí, promoted joint actions by the Agriculture Development Ministry (Ministerio de Desarrollo Agropecuario) (MIDA) and Instituto de Investigación Agropecuaria de Panamá (IDIAP) (Pérez, 2006) to prospect for biocontrol agents in areas close to the *Hypothenemus hampei* (Ferrari) infestation foci and several strains of *Beauveria* sp. were identified (Morales *et al.*, 2009). Classical biocontrol of *H. hampei* began in 2006 with the release of 1,600,000 adult *Prorops nasuta* Waterston, imported from Colombia, on 18 farms located in Renacimiento, Chiriquí, Panama (Pérez, 2006). The efficiency of *Beauveria bassiana* (Bals.-Criv) Vuill applications and the mortality rates of releases of *P. nasuta* and *P. coffea* against the coffee berry borer were between 48% and 54%, respectively.

Thrips palmi Karni caused severe damage to Cucurbitaceae in Herrera, Panama, affecting fruit quality and yields (Vásquez and Barba, 2013). Its population dynamics were studied in crops and non-cultivated host plants (Barba, 2015; Barba and Suris, 2015), including presence of natural enemies, and a conservation biocontrol programme was implemented (Barba, 2007). Four possibly new *Orius* species (Hirano, 2009), all predators of *T. palmi*, were evaluated in the laboratory. *Orius insidiosus* Say was mass reared, using an artificial diet based on *Sitotroga cerealella* Olivier eggs in a solution of maize pollen and honey (1:1), and *Phaseolus vulgaris* L. beans were used as an oviposition substrate (Barba and Suris, 2015), which yielded promising results in the laboratory.

Oebalus insularis Stal is the main rice pest that causes direct damage and significant losses in the milky stage of rice (Zachrisson and Martinez, 2011; Zachrisson *et al.*, 2014a). In addition, even low numbers of larvae of *Rupela albinella* (Cr.) and *Spodoptera frugiperda* (J.E. Smith) may cause severe damage during the vegetative phase of rice. The egg parasitoids *Telenomus rowani* (Gaham), *Trichogramma pretiosum* Riley and *Telenomus podisi* Ashmead have been shown to be effective agents in the control of *R. albinella*, *S. frugiperda* and *O. insularis*, respectively (Zachrisson, 2009). In addition, new associations of *T. podisi* with *Tibraca limbativentris* (Stal) and *Euschistus* Rolston showed parasitism rates above 80% in extensive rice production areas in Coclé, Panama (Zachrisson *et al.*, 2014b). The natural parasitism by species such as *T. rowani* and *T. podisi*, which reduce *R. albinella* and *O. insularis* populations, respectively, can be promoted by conserving natural reservoirs of weed species (Zachrisson and Polanco, 2017).

The production of entomopathogenic agents, mainly *Metarhizium anisopliae* (Metchnikoff) Sorokin, *B. bassiana* and *Isaria* sp., is currently being implemented and stimulated by the development of a collection of entomopathogenic fungi located at the Central Research Center (CIAC) of the IDIAP. The use of *Isaria* sp. to manage *H. hampei*, despite the lack of personnel trained in microbial control, is also an important accomplishment. Furthermore, there are commercial companies that produce microbial control agents at the local level, strengthening these projects.

Due to increased international trade, the number of invasions by alien species, which are often polyphagous, has also increased. Given this situation, classical biocontrol programmes were strengthened, and international agreements between Empresa Brasileira de Pesquisa Agropecuária (Embrapa) and IDIAP were implemented to encourage research to identify potential invasive species from the Americas. As a result, biological studies were promoted *in situ* to understand the behaviour of these insects and their adaptation to cultivated and wild plants.

23.4 New Biological Control Developments in Panama

The development of artificial diets for the multiplication of key pests is a priority to improve and economize mass rearing of natural enemies for augmentative biocontrol programmes. Currently, artificial diets for *S. frugiperda*, *D. saccharalis*, *D. tabernella*, *H. hampei* and *O. insularis* are formulated and evaluated. Also, mass production of *Trichogramma* sp. and *T. podisi* in biofactories is under implementation with the goal of controlling a large number of lepidopteran (Noctuidae, Pyralidae) and heteropteran (Pentatomidae) pests that affect the main agricultural crops.

As well as developments in the area of augmentative biocontrol, Panama is working on conservation biocontrol. Host plants of the pest *O. insularis* and its parasitoids in weeds occurring

Table 23.2. Application of biological control in Panama.

Biocontrol agent	Pest / crop	Type of biocontrol[a] / since	Effect[b] / area (ha) under biocontrol[c]
Eretmocerus serius	Citrus blackfly in citrus	CBC / 1931	+ / ? terminated in 1943
Cotesia flavipes and *Paratheresia claripalpis*	Sugarcane borers in sugarcane	ABC / 1970	+ / 38,629[b]
Complex of predators and parasitoids	Whitefly in tomato, other vegetables	NC / 1990	+ / 2,863[b]
Complex of parasitoids	*Liriomyza huidobrensis* in vegetables	NC / 1991	± / 553
Complex of parasitoids	Diamondback moth	ABC / 1998	± / 0.5
Prorops nasuta	Coffee berry borer in coffee	CBC / 2006	± / 19
Complex of predators and parasitoids	Rice stink bug in rice	ConsBC / 2009	± / 177

[a]Type of biocontrol: ABC = augmentative, CBC = classical, ConsBC = conservation biocontrol; NC = natural control;
[b]Effect: + = success, ± = partial success,
[c]Area of crop harvested in 2017 according to FAO (http://www.fao.org/faostat/en/#data/qc)

in or near rice fields have been studied and the high potential of some of the weeds to be reservoirs of egg parasitoids of this rice pest has been confirmed. The weed–pest–parasitoid complex enables studies in the field of chemical ecology, particularly for determination of the role of volatile compounds emitted by the weeds to attract pentatomid egg parasitoids.

There are no complete data about crops and areas under biocontrol in Panama, as many of the projects are under development. However, the partial data available indicate that about 42,241 ha are under biocontrol (Table 23.2).

23.5 Acknowledgement

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(References with grey shading are available as supplementary electronic material)

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12 CABI INVASIVES SERIES

Biological Control in Latin America and the Caribbean

Its Rich History and Bright Future

EDITED BY **JOOP C. VAN LENTEREN, VANDA H.P. BUENO, M. GABRIELA LUNA** AND **YELITZA C. COLMENAREZ**

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