Arthropod-Plant Interactions

Progress in Biological Control

Volume 14

Published:

Volume 4

J. Gould, K. Hoelmer and J. Goolsby (eds.):

Classical Biological Control of *Bemisia tabaci* in the United States. 2008

ISBN 978-1-4020-6739-6

Volume 5

J. Romeis, A.M. Shelton and G. Kennedy (eds.):

Integration of Insect-Resistant Genetically Modified Crops within IPM Programs. 2008

HB ISBN 978-1-4020-8372-3; PB ISBN 978-1-4020-8459-1

Volume 6

A.E. Hajek, T.R. Glare and M.O'Callaghan (eds.):

Use of Microbes for Control and Eradication of Invasive Arthropods. 2008

ISBN: 978-1-4020-8559-8

Volume 7

Jonathan G. Lundgren:

Relationships of Natural Enemies and Non-Prey Foods. 2008

ISBN: 978-1-4020-9234-3

Volume 8

S.S. Gnanamanickam:

Biological Control of Rice Diseases

ISBN: 978-90-481-2464-0

Volume 9

F.L. Cônsoli, J.R.P. Parra and R.A. Zucchi (eds.):

Egg Parasitoids in Agroecosystems with Emphasis on *Trichogramma*

ISBN: 978-1-4020-9109-4

Volume 10

W.J. Ravensberg:

A Roadmap to the Successful Development and Commercialization of Microbial Pest Control Products for Control of Arthropods

ISBN: 978-94-007-0436-7

Volume 11

K. Davies and Y. Spiegel (eds.):

Biological Control of Plant-Parasitic Nematodes. 2011

ISBN 978-1-4020-9647-1

Volume 12

J.M. Mérillon and K.G. Ramawat (eds.):

Plant Defence: Biological Control

ISBN 978-94-007-1932-3

Volume 13

H. Roy, P. De Clercq, L.J. Lawson Handley, J.J. Sloggett, R.L. Poland and E. Wajnberg (eds.):
Invasive Alien Arthropod Predators and Parasitoids: An Ecological Approach

ISBN 978-94-007-2708-3

For further volumes:

<http://www.springer.com/series/6417>

Guy Smagghe • Isabel Diaz
Editors

Arthropod-Plant Interactions

Novel Insights and Approaches for IPM

Springer

Editors

Guy Smagghe
Department of Crop Protection
Faculty of Bioscience Engineering
Ghent University
Coupure Links 653
Ghent, Belgium

Isabel Diaz
Centro de Biotecnología y
Genómica de Plantas
Universidad Politécnica de Madrid
Autovía M40 (km 38)
Pozuelo de Alarcón, Madrid, Spain

ISBN 978-94-007-3872-0

ISBN 978-94-007-3873-7 (eBook)

DOI 10.1007/978-94-007-3873-7

Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2012936129

© Springer Science+Business Media B.V. 2012

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword

Insect pests constitute a very important constraint in global agriculture. The potential yield of all agricultural crops and/or farmer income are reduced substantially due to direct or indirect effects of insect attack. In order to control damage to crops by insects hundreds of millions of US\$ need to be spent annually on crop protection chemicals such as insecticides. In addition to the financial cost of insecticides, we are becoming increasingly aware of the environmental and health hazards associated with conventional pesticides. In more recent years biotechnology has provided additional tools to limit the damage caused by insects while at the same time minimizing or perhaps eliminating some or all of the environmental and health risks associated with chemical insecticides. This is even more critical as pressure mounts on regulators to put sustainability, health and environmental protection high on their list of criteria for evaluating the fate of existing or new chemical pesticides.

In order to harness the power of biotechnology in the context of crop protection in its broadest senses it is crucial that we develop an in depth understanding of biological, developmental and evolutionary aspects of the complex interactions between crop plants and their insect pests.

One mechanism through which plants develop resistance against their insect pests is through constant evolution of endogenous defence pathways stimulated by insect attack. The power of next generation sequencing technologies for plants and also their insect pests has the potential to provide invaluable information through comparative genomics that can be used to design better strategies for IPM combining conventional as well as molecular/biotechnological approaches. To that effect bioinformatic tools and resources as well as sophisticated algorithms for data analysis and interpretation are already making an impact in terms of new potential strategies for insect pest control.

Little is known about the mechanism responsible for the physiological adaptation of the insect gut when insects feed on living plant material. However more information is emerging from studies on the digestion of plant tissues by insects feeding through different means (e.g. leaf chewing or phloem sucking) and elucidation of factors which determine the physiological processes leading to

adaptation and subsequent resistance of feeding insects to deal with plant secondary metabolites and insecticidal proteins. More recently it has been established that insect feeding on plants are adapted to circumvent the effects of insecticidal proteins of plant origin that specifically target their digestive enzymes. Thus transcriptome analysis of phytophagous insects is revealing new aspects of the physiology of the insect gut that may be involved in the adaptation to plant defences. However, investigations aiming towards elucidating both components of the plant-insect interaction at the whole genome level are needed in order to develop a better understanding of this interaction.

In order to remain one step ahead of the pest and move away from reliance on single resistance genes, inevitably resulting in a never ending co-evolution of plants and their insect pests, multi-mechanistic resistance must be breed/ engineered into our crops. Transgenic crops are an essential and inevitable component towards sustainable food security as part of IPM where molecular breeding strategies are also used to develop pest resistant crops. In depth knowledge of how plants respond to insect attack, at the molecular level is very important in order to identify appropriate genes, gene families or markers (QTLs) for subsequent breeding programmes.

Biological control has rapidly become an essential component of modern horticultural. However most success stories come from greenhouse applications with open field biological control presenting a big challenge. More recently encouraging results are emerging from studies involving the development of targeted precision biocontrol and pollination enhancement using different species of bees. The “entomovector” technology utilizes insects as vectors of biological control agents targeting plant pests and diseases. The technology depends on bee management, manipulation of bee behavior, components of the cropping system, and on the plant-pathogen-vector-antagonist-system.

When insects commence feeding on a plant the amount of volatile compounds emitted by the plant under attack increases dramatically. Concomitantly, the composition of the volatiles changes often in such a way to attract natural enemies of the pest or on occasion to increase repellency to herbivores. Herbivore-induced volatiles promote a natural form of biological pest control referred to as “indirect plant defense”. It has been suggested that this phenomenon could be exploited to enhance crop protection. Different approaches are being explored to manipulate indirect defenses through the application of synthetic volatiles or via transgene-mediated modulation of plant-volatile production.

The pace of the development of insect-resistant crops through genetic engineering has increased dramatically since the commercial introduction of the first crop plants (cotton and corn) expressing a single *Bacillus thuringiensis* (Bt) toxin, 15 years ago. Amongst the key benefits of these first generation insect resistant crops has been a huge reduction in pesticide application. In order to address issues of durability of resistance and also to extend the technology to pests outside the host range of Bt, substantial investments have been made in the search for alternative/ complementary strategies to protect crops from insect pests. Technological advances in plant genetic transformation provided tools for transferring multiple

pest resistance traits into agronomically important crops while novel strategies based on a better understanding of endogenous plant resistant mechanisms are emerging and appear to constitute further elements in our efforts to achieve durable resistance against insect pests.

Transgene-encoded dsRNAs provide interesting alternative strategies for insect pest control which can either be exploited independently or complement *Bacillus thuringiensis* (*Bt*) toxins in insect management programs. Transgenic crops with such “pyramided” insect-protection traits are most likely superior to single-trait crops with respect to development of resistance by insect pests.

Transgenic (GM or GE) crops are subjected to safety and environmental risk assessment which is far more stringent than for conventionally bred varieties. In the European Union, regulation is influenced by political expediency, and implementation of regulatory assessments by scientifically competent bodies are almost invariably overruled. This anti-science approach to regulation in combination with further complex, onerous and hardly justified policies on traceability, labeling, coexistence, socio-economic issues and liability constitute de facto trait barriers to legitimize the stance of the EU towards GM crops.

Paul Christou

Paul Christou

Currently Dr. Christou works at Universitat de Lleida as an ICREA Research Professor and head of the Applied Plant Biotechnology Laboratory.

He received BS degree in Chemistry and PhD in plant biochemistry from University College London, worked as senior scientist at Agracetus Inc. Madison WI USA. Subsequently head of Molecular Biotechnology Unit, John Innes Centre, Norwich UK and then was head of Crop Genetics and Biotechnology Department at the Fraunhofer Institute for Molecular Biotechnology and Applied Ecology, Aachen/Schmallenberg, Germany.

For the past several years he has investigated the organization of foreign genes in important crops such as maize, rice and wheat and its impact on transgene expression levels and stability. Applied aspects of our research include production of high value recombinant pharmaceuticals (vaccines and antibodies) in plants for use in human health and veterinary medicine; engineering crop plants for enhanced nutrition and novel strategies of sustainable and environmentally friendly agriculture using transgenic approaches, all with emphasis on developing countries, poverty alleviation and food security. His group is heavily involved in training and capacity building in the area of plant biotechnology focusing on developing countries.

Dr. Christou is Chief Editor of Transgenic Research and Molecular Breeding and belongs to the Editorial Advisory board of several scientific journals. He is author of books, chapters in books and has published near 150 articles in the most prestigious peer reviewed journals. He is also author of several patents, has supervised PhD theses, has imparted lectures in international meetings and workshops and has been the coordinator or principal investigator of research projects financed by international public and private institutions.

Progress in Biological Control

Series Preface

Biological control of pests, weeds, and plant and animal diseases utilising their natural antagonists is a well-established and rapidly evolving field of science. Despite its stunning successes world-wide and a steadily growing number of applications, biological control has remained grossly underexploited. Its untapped potential, however, represents the best hope to providing lasting, environmentally sound, and socially acceptable pest management. Such techniques are urgently needed for the control of an increasing number of problem pests affecting agriculture and forestry, and to suppress invasive organisms which threaten natural habitats and global biodiversity.

Based on the positive features of biological control, such as its target specificity and the lack of negative impacts on humans, it is the prime candidate in the search for reducing dependency on chemical pesticides. Replacement of chemical control by biological control – even partially as in many IPM programs – has important positive but so far neglected socio-economic, humanitarian, environmental and ethical implications. Change from chemical to biological control substantially contributes to the conservation of natural resources, and results in a considerable reduction of environmental pollution. It eliminates human exposure to toxic pesticides, improves sustainability of production systems, and enhances biodiversity. Public demand for finding solutions based on biological control is the main driving force in the increasing utilisation of natural enemies for controlling noxious organisms.

This book series is intended to accelerate these developments through exploring the progress made within the various aspects of biological control, and via documenting these advances to the benefit of fellow scientists, students, public officials, policy-makers, and the public at large. Each of the books in this series is expected to provide a comprehensive, authoritative synthesis of the topic, likely to stand the test of time.

Heikki M.T. Hokkanen, Series Editor

Preface

The book consists of multiple chapters by leading experts on the different aspects in the unique relationship between arthropods and plants, the underlying mechanisms, realized successes and failures of interactions and application for IPM, and future lines of research and perspectives. Interesting is the availability of the current genomes of different insects, mites and nematodes and different important plants and agricultural crops to bring better insights in the cross talk mechanisms and interacting players. This book will be the first one that integrates all this fascinating and newest (from the last 5 years) information from different leading research laboratories in the world and with perspectives from academia, government and industry.

Contents

1	Co-evolution of Genes for Specification in Arthropod-Plant Interactions: A Bioinformatic Analysis in Plant and Arthropod Genomes	1
	Manuel Martinez	
2	The Impact of Induced Plant Volatiles on Plant-Arthropod Interactions	15
	Juan M. Alba, Petra M. Bleeker, Joris J. Glas, Bernardus C.J. Schimmel, Michiel van Wijk, Maurice W. Sabelis, Robert C. Schuurink, and Merijn R. Kant	
3	Physiological Adaptations of the Insect Gut to Herbivory	75
	Félix Ortego	
4	Successes and Failures in Plant-Insect Interactions: Is it Possible to Stay One Step Ahead of the Insects?	89
	Angharad Gatehouse and Natalie Ferry	
5	Multitrophic Interactions: The Entomovector Technology	127
	Guy Smagghe, Veerle Mommaerts, Heikki Hokkanen, and Ingeborg Menzler-Hokkanen	
6	Biotechnological Approaches to Combat Phytophagous Arthropods	159
	Isabel Diaz and M. Estrella Santamaria	
7	Use of RNAi for Control of Insect Crop Pests	177
	Luc Swevers and Guy Smagghe	
8	Regulatory Approvals of GM Plants (Insect Resistant) in European Agriculture: Perspectives from Industry	199
	Jaime Costa and Concepcion Novillo	
	Index	217