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BOOK REVIEW

Arthropod-Plant Interactions: Novel Insights and Approaches for IPM

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The book is the fourteenth in the series Progress in Biological Control and begins with a foreword by Paul Christou, which is followed by a general preface by the series editor, Heikki M.T. Hokkanen, in which the aim of the project is clearly spelled out, namely to speed up the development of biological control by exploring and documenting the progress made in the various sectors of this field.

The foreword by Paul Christou, whose *curriculum vitae* is also included, reaffirms that there is an evident will to discover and exploit the known relations between insects and plants in order to reduce to an increasing extent the adoption of chemicals in Integrated Pest Management (IPM) programs, also by making the maximum use of biotechnologies, which the author believes able to limit damage from insects and thus reduce, if not eliminate, the use of insecticides. He also reminds us of the fact that plants develop resistance against their insect enemies and how the latter overcome such defenses. And he outlines the problems of plant-insect relations that are open to solution or possible solution, emphasizing how to manage them through biotechnological techniques.

In the preface to the volume, the editors express, in just a few lines, their satisfaction at having put together a book where the various chapters, eight in all, together offer an overview of the different aspects of the relations between arthropods and plants and how much of this knowledge can be effectively applied in IPM programs. In this context the authors believe that only the results of the very latest research, carried out in leading laboratories across the world, have had a significant impact.

This is followed by a table of contents giving details of the topics covered by each of the eight chapters and the bibliographical apparatus that gives them their form and substance. In the PDF version of the book, by clicking on the references written in light blue the reader can go straight to the item listed in the bibliography.

The eight chapters were written by a total of twenty-two authors, one or more of whom contributed to each chapter.

The opening chapter of the book focuses on the interaction between arthropods and plants, in particular describing the co-evolutive manifestations that underpin the genetic programs of aggression and defense in the conflicting parties - arthropods and plants - requiring integrations of macro evolutionary models with functional, genetic and ecological evidences. There follows a discussion on the state of genetic sequencing in plants and harmful arthropods (insects and mites) for whom little has been or is being done in this direction. It is important, in fact, to identify the presumed genomic sequences that encode the protein, since these are critical in the relation between infesting arthropods and plants. Therefore, it is hoped that new comparative genome databases will be created in order to increase the number and accuracy of the instruments to help plants to combat harmful arthropods, and the same must be done to identify the families of genes that encode the proteins harmful to phytophagous insects.

The second chapter deals with the indirect defense of plants against insect pests, making use of organisms that they attract towards their prey by emitting semiochemicals. This is an important defense mechanism in response to an aggressor that the plant ‘doesn't totally trust’ and so implements constitutive defenses, which are differentiated on a stable basis and are not induced temporarily and specifically for each aggressor. The article goes on to outline the single defense strategies employed by the plant against all aggressors, highlighting the central role played by two hormones: salicylic acid and jasmonic acid. It then describes the ways in which the aggressor is able to activate the defense mechanisms of the plant, including a combination between mechanical damage and salivary elicitors. In order for this indirect defense to become a sustainable opportunity in an IPM process, the entomophagous insects (in particular the parasitoids) need to be “trained” to respond to the synthetic signal with a reward. The authors conclude by saying that it is hard to believe that we are not able to orchestrate the indirect defenses and compete with natural selection.

The third chapter gives an account of all that insects have done to become phytophages, that is to say consumers of living plants as opposed to decomposed material. In order to reach this state they had to adapt the physiology of their digestive system, modifying the gut, the organs for grasping food (solid or liquid) and the digestive enzymes. The result of this choice is that today herbivorous insects constitute over a half of all living species. As well as being able to digest this “new food” these insects also had to come to terms with the chemical defenses of the plant. The organization of the digestive process is hypothesized to be related to the phylogenetic position of the insect rather than to its feeding habits.

The fourth chapter consists mainly of an assessment of how successful or unsuccessful transgenic products and molecular breeding approaches have been in avoiding infestations, an analysis based on the balance between the mortality rate of the insect and the effects on non target subjects. The evaluation is sustained by the authors' conviction that it is impossible not to use transgenic products if we wish to feed the world. The proposed analysis considers how much is known about plant breeding and varietal resistance using endogenic defenses in the form of indirect defenses (production of volatile organic compounds), the detoxification of potentially toxic secondary metabolites of the plant by harmful insects and the modulation of the response to the wound by the insects. With regards GM plants, the authors speak extensively of those (maize, cotton and potatoes) that have been induced to express the insecticide protein derived from *Bacillus thuringiensis* (*Bt*), against which populations of harmful insects have now become resistant. This fact is particularly significant because the researchers wish to modify the biology of an organism at a different trophic level to that of the plant. Finally, there is a real risk of creating problems for non-target arthropods. Monarch butterfly larvae fed with leaves of the host plant sprinkled with *Bt* pollen showed a considerably reduced survival rate and a lower consumption of the treated pabulum. A subsequent analysis of the toxicity of *Bt* pollen from different crops revealed that *Bt*-maize does not create particular risks for larvae of *Danaus plexippus*, and the same is true for the larvae of *Papilio polyxenes*. In any case, the indications of sensitivity towards *Bt* pollen by non-target organisms need to be assessed case by case. Moreover, studies on the effect of GM plants at a higher trophic level, in other words on parasitoids and predators that ingest the toxin absorbed by the phytophages on which they feed, show that *Bt* toxin has a limited influence. Another factor taken into consideration, again with regard to the non-target insects, is the risk run by pollinators when exposed to *Bt* toxins found in the pollen and tissues of GM plants. Adult bees and larvae were not seen to be intoxicated. GM plants resistant to harmful insects do not therefore appear to have any negative effects on beneficial insects.

Plants resistant to harmful insects with genes which constitutively express defensive protein include those that express inhibitor enzymes interfering with the digestion. A prerequisite of the toxic action of lectins is the fact that they bind themselves to the epithelial cells of the intestine and may reach the haemocoel and enter the circulatory system, determining a systematic toxic effect. Furthermore, the expression of lectins in GM plants is not sufficient to consider them commercially viable. Lectins, moreover, are generally toxic for mammals.

The development of a second generation of GM plants with a greater and longer resistance includes the insecticide expression of multiple genes. For example, the expression of the *Photorhabdus* toxin (a symbiotic bacterium of entomopathogenic nematodes) in *Arabidopsis* significantly increased insect mortality. A similar protection is obtained through the peptide hormones of insects. In fact tomato produces peptic insecticides when the peptides of the insect replace the peptide systemin region of the prosystemin.

Currently research is focusing on the evolution of resistance in populations of harmful insects to the insecticide molecules of GM plants. It is hoped that the expression and interaction of genes (functional genomics) will give rise to a tolerance to biotic stress. The analysis of the map, of the DNA sequencing of plants, and of information in the genome sequences will allow us to study the genes that control complex aspects such as transgenic breeding strategies.

In the context of functional genomics, the authors consider studies on genetic expression at the level of transcriptome and proteome, which are reprogrammed in the leaves of wheat attacked by the aphid *Sitobium avenae* making it possible to identify the genetic properties involved in the defense against phytophages that can be exploited in direct strategies for wheat breeding. The response of wheat plants to aphids is not specific. In fact a significant response can be elicited from an artificially provoked wound. Therefore, it would appear that transgenic enhancement of the response to the wound can also increase the resistance to insects. The response to aphids observed in wheat was divided into 5 higher categories.

The chapter closes with a reference to the use of metabolomic analysis to identify unexpected bioactive compounds involved in the ecological interactions between plants and their phytophages which have shown to be potentially useful for this aim.

The fifth chapter deals with the technology that uses insects to achieve a focused distribution of biological agents for the management of insect populations and diseases. For this purpose the ecological function of biocontrol and pollination has been explored and supported to potentiate this innovative form of control. Working with entomovectors, dispensers, transporters and the biological control agents (BCA), excellent results have been obtained. These are discussed in two cases that use the biofungicide Prestop-Mix to control *Botrytis cinerea* in strawberries when distributed by *Apis mellifera* in the field and *Bombus terrestris* in the greenhouse. In conclusion, the success of this method of biological control for plant pathogens depends on how frequently the insect carriers of BCA visits the crop.

The sixth chapter is devoted to an analysis of the combination of potential and currently used biotechnological systems adopted to combat mites and harmful insects through the use of defense genes. The authors discuss the positive effects attained by new technological systems with a view to a sustainable agriculture. The limited or lack of sensitivity of *Bt* toxin towards aphids and mites led to the search for alternative defense strategies. Research therefore focused on plant genes with insecticide and acaricide properties and molecules or toxins from multiple sources which when expressed in a variety of plants increases their resistance to a wide range of harmful arthropods, as demonstrated in the lab. More precisely, the authors underline how a high number of publications report the potential of synthesized plant proteins in response to the plant-phytophagous relation. The inhibitors of the hydrolytic enzymes, including protease and amylase, act as target pseudosubstrates for digestive enzymes, interfering with the digestion of the phytophages and preventing the assimilation of proteic compounds and carbohydrates in their diet. GM plants with such capacities, of which a list is given, do not show a complete resistance to insect damage, neither do they determine a high mortality rate. This becomes evident when GM plants coexpress a combination of hydrolytic enzyme inhibitors and other genes that express resistance phenomena. Such potentiation has also been seen in GM plants that express *Bt* toxins or lectins.

Finally, the authors suggest, as already proposed in chapter four, that instead of *Bt* toxins, GM plants could be induced to express those of symbiotic bacteria of entomopathogenic nematodes such as *Photorhabdus* and *Xenorhabdus* that have genes that encode sets of insecticidal toxins.

A further possibility for plant defense against harmful insects is to induce the plants to express regulatory transcription factors in order to activate defense processes against insects, although at the expense of productivity.

The seventh chapter considers the use of RNA interference (RNAi) as an alternative method to protect crops against insect damage. The biological functions of RNAi in insects are discussed, focusing on the development of this new technology in the management of harmful insects. Details are given of the delivery methods of double-stranded RNA (dsRNA) and its pathway as it is absorbed by the insects, in particular plant engineering aimed at the suppression of gene expression in a phytophagous insect; its specific gene and the selective characters of the insect confirm that the application of this method respects the environment.

In the eighth and final chapter the authors suggest that GM plants can offer a significant contribution to a sustainable agriculture, giving as an example the reduction in the use of insecticides in GM plants of maize and cotton that are resistant to harmful insects. In this context they allude to the regulatory supervision of GM crops and their products in the EU, and in the following paragraph they wonder whether an adequate process is currently being developed for their approval. The analysis continues with an assessment of the risk and the way society views GM products. The authors then underline how the presence of GM organisms in food must be clearly indicated on the label and they then stress the importance of their traceability and segregation in storage and transport. Another paragraph deals with the conclusions on monitoring and surveillance in the EU. The chapter ends with a paragraph pointing out that GM varieties of plants are patentable in the USA (20 years of commercial rights) but not in the EU, where there is however legal protection for biotechnological inventions making use of GM technology.

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