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出版规划项目

陈宗懋

—— 主编 ——

茶树害虫

化学生态学

CHEMICAL ECOLOGY
OF TEA PESTS

上海科学技术出版社



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内 容 提 要

本书共分 14 章,内容包括:中国茶树害虫区系及其演替;茶园中挥发性化合物的组成、合成途径和功能;挥发物的收集和分析方法;茶树害虫的口器类型与虫害诱导挥发物;茶树—害虫—天敌间的化学通讯联系;茶树害虫诱导挥发物中活性成分 EAG/GC-EAD 的筛选;以视觉和嗅觉为基础的茶树害虫的寄主定位与调控;茶小卷叶蛾性信息素的研究;茶园害虫的性信息素管理;茶蚜和黑刺粉虱的化学生态学;茉莉酸甲酯诱导的茶树间接抗虫性的研究;昆虫刺探电位图谱(EPG)技术在茶树抗性检测中的应用;拒食机制在茶树害虫防治中的应用;以化学生态学构建茶园害虫无公害治理的理论与实践等。

本书是作者多年研究的成果及解决来源于生产实际问题的成果,涵盖茶树害虫绿色防治基础研究到应用技术研究的各个方面,提出了利用化学生态学原理治理茶树害虫防治的新思路。同时,本书作者还在总结国内外关于茶树害虫性信息素的研究进展基础上,结合茶树害虫化学生态学创造性地构建了我国化学生态学的无公害防治技术体系,是在认识和方法方面对茶树害虫综合治理的新提升,具有广泛的实用意义,对我国开展化学生态学在农作物的探索和研究也具有重要的指导作用。

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蔡晓明

序

昆虫化学生态学是现代生态学的一个重要分支学科,是昆虫学、植物保护学、生态学、生物化学和分子生物学等多个学科交叉渗透而形成的一门新学科。早在 20 世纪 50 年代,Butenandt 研究团队在德国完成了家蚕性信息素(bombykol)的鉴定,标志着世界上第一个昆虫性信息素问世。在这个创新成果发布后 5 年,Wright(1964)就在一篇题为《农药以后是什么》的论文中提出环境安全的害虫防治设想。因此,可以认为家蚕性信息素的发现开启了昆虫化学生态学研究殿堂的大门。近五十年来,昆虫化学生态学取得长足的进步,引起了科学界的广泛重视,研究已从性信息素延伸到信息素、从化学通讯到行为调控、从诱导直接防御到间接防御、从化学信息识别到信号传递等诸多领域;研究的范围也日益扩展,涉及种内昆虫之间、种间昆虫之间、昆虫与植物之间、昆虫与微生物之间,等等。如此复杂的研究领域、广宽的研究范围显示了化学生态学的广泛适应性,也显示出深邃的理论价值和良好的应用前景。本世纪来,昆虫化学生态学的研究理论已开始从实验室向生产实践试探进军。

茶叶生长在我国暖温带和亚热带地区,常年害虫发生严重,化学农药的频繁使用不仅造成了农药残留问题,更导致害虫产生抗药性以及次期性害虫大发生等问题。因此,人们更期望采用无害化的治理方式进行绿色防控。在这样的理念下,人们对茶树昆虫化学生态学寄予更高的期望。上世纪 90 年代初,以陈宗懋院士为首的研究团队开展了茶树害虫化学生

态学研究,取得了不少成果。在这十余年间,他们对茶树挥发物展开了系统的研究,不仅研究了不同茶树害虫诱导茶树挥发物的指纹谱,而且也研究了挥发物在茶园生态系中的形成和动态变化及其对害虫种群的生态调控功能。他们所做的研究已逐渐从理论基础深入到了生产应用,展示了较大的发展空间。近年来,尽管国内已出版了一些有关昆虫化学生态学的专著,但涉及范围较广。此次,陈宗懋院士团队出版的《茶树害虫化学生态学》一书,无疑对推动我国昆虫化学生态学研究领域的发展,特别是对未来利用化学生态学原理实现茶树害虫的绿色调控研究将会起到巨大的推动作用,值得祝贺。更期待茶树害虫化学生态学研究不断取得突破性的成果。

中国工程院院士 郭予元

2013年3月

Preface

Insect chemical ecology, an important branch of modern ecology, is a new intersectional discipline crossed with entomology, plant protection, ecology, biochemistry and molecular biology. As early as 1950s, the world first *Bombyx mori* sex pheromone (Bombykol) was identified by Butenandt's research team in Germany. Five years after the innovation, the hypothesis of pest control with environmental safe was put forward by Wright (1964) in his article entitled "what is after the pesticide". Therefore, the discovery of silkworm sex pheromone could be regarded as opening the door to the palace of Insect Chemical Ecology. Insect Chemical Ecology aroused extensive attention of the scientific community since the great progress was made in the last fifty years. The research intensions in Insect Chemical Ecology has extended from the sex pheromone to general pheromones, from the chemical communication to behavioral regulation, from the induced direct defense to indirect defense, from the identification of chemical information to signal transduction and many other areas. And the investigation scopes have extended increasingly also, involving intraspecific insects, interspecific insects, between insects and plants, insects and micro-organisms, and so on. Such a study with complex and wide field shows the extensive adaptability of chemical ecology and also shows the deep theoretical value and a good prospect for application. In this century,

the Insect Chemical Ecology theory has begun to be tested from the laboratory to the application in the production.

The tea plants were grown in warm temperate and subtropical regions in our country, suffered heavily from insect pests. Frequent use of chemical pesticides is not only caused pesticide residues, but also lead to pest resistance, and outbreaks of the secondary pests. Therefore, it is more desirable to use harmless “green techniques” for pest management. Under this concept, people placed high expectations on tea pest chemical ecology. In the early 1990s, the research team headed by Academician Zongmao Chen conducted the research on tea pest’s chemical ecology, and got a lot of achievements. In more than ten years, they launched a systematic study on tea volatiles. They investigated on different tea pest induced volatiles fingerprints, as well as the formation, dynamic characteristics and ecological regulation to pest populations in tea plantation ecosystem. Their researches have gradually turned from the theory to application, showing a larger prospect. In recent years, a number of monographs on Insect Chemical Ecology have been published in our country, however, these publications are involves wider scopes of plants. This time, academician Chen’s team planned to publish a “tea pest chemical ecology”, it will undoubtedly promote the development of Insect Chemical Ecology in China, especially will promote the use of chemical ecology in tea pest management, it is worthy of our congratulations. We are hope that tea pest chemical ecology continues to acquire a breakthrough in the future research.

Academician of the Chinese Academy of Engineering

Yuyuan GUO

March 2013

前 言

昆虫化学生态学主要研究昆虫种内、种间以及与其他生物之间的化学信息联系和相互作用,是研究化学信号在昆虫行为、生活、繁衍中的作用与功能以及昆虫和植物的次生代谢物间的协同进化领域方面的一门学科。昆虫化学生态学不仅是昆虫学的一门分支学科,更是当前国际昆虫学研究领域和化学生态学研究领域最活跃的分支学科之一。半个多世纪来,昆虫化学生态学的发展在广度上与生物化学、分子生物学、生态学、植物生理学、昆虫生理学、微生物学、电生理学、行为学、信息学、环境科学等多门学科交叉融合。学科的交叉融合是 20 世纪社会繁荣和发展的一个重要因素,也反映了科学理念的进步和合理化。化学是一门古老的学科,许多从化学学科中诞生的成果改变了人类的生活。例如,1843 年化学肥料的问世使得农作物的产量成倍的增长;1938 年化学农药的问世控制了有害生物,保证了农业的丰收。然而,化学肥料和农药的大量使用导致了人们没有估计到的后果:化肥的过量使用造成了环境的严重污染,甚至引起了大气环境的恶化;化学农药的过量使用产生了农产品的农药残留、有害生物的抗性和再猖獗。这不是化学学科的过错,而是因为在当时化学学科的发展中还缺乏和生态学相联合的理念。1962 年美国海洋生物学家 Rachal Carson 出版了一本名为《Silent Spring》(寂静的春天)的著作,用科学的预言道出了未来的可能后果。这本著作的问世可以看成为化学生态学的前奏。化学生态学的诞生使得化学和生态学实现了交叉,使得化学学科武装了生态学的理念,成为一门在自然科学中异常活跃和思维新颖的新学科。

从 1959 年象征着昆虫化学生态学诞生的第一个昆虫信息素的发现至今,昆虫化学生态学的研究渐趋深入,研究领域日趋拓宽,从早期性信息素

(sex pheromone)研究开始,延伸至生物间的生化他感作用(allelopathy)、昆虫信息素(pheromone)和行为、植物挥发物(volatile)对昆虫的间接抗性、昆虫种群和其他生物间的化学通讯(chemical communication)和化学传感(chemosensory)、昆虫化学信号(chemical signalling)与种群调控等领域。在研究水平的宏观深度上从个体水平发展到种群、群落和生态系统,在微观上从个体水平发展到分子水平、基因组学水平。

茶叶生长在我国暖温带、亚热带和热带地区,常年害虫发生严重,化学农药的频繁使用不仅造成了农药残留问题,更导致害虫产生抗药性以及次期性害虫大发生等问题。茶叶是一种对人体健康有益的饮品,因此人们更期望采用无害化的治理方式进行绿色防控,以获得一种无污染的健康饮品。在这样一个大背景下,本人及研究团队于20世纪90年代后期开始了茶树害虫化学生态学的研究和探索。历时10余年的研究,得到了国家自然科学基金、国家茶叶产业技术体系、国家科技支撑计划、公益性行业科研专项、浙江省科技厅重大项目、浙江省自然科学基金等项目的资助,使得我们在茶树害虫诱导茶树挥发物的指纹谱、挥发物在茶园生态系统中的形成和动态变化及其对害虫种群的生态调控功能等方面取得了一些成果。尽管国内已出版了一些有关昆虫化学生态学的专著,但多以不同角度总结某个方面的研究成果。本书写作对象围绕茶树进行,对茶树与害虫之间的关系进行了较为透彻的阐述。书中以本研究团队的研究成果为主,并对历史资料的收集和整理结合国际发展趋势进行撰写。这样,在理论上可为害虫的化学生态学研究提供一定的参考,在实践上也可作为茶树害虫的无害化治理提供新思路。我们期望这本书的出版对用化学生态学的理念和研究实践提高我国茶产业有害生物的绿色防控有所促进,同时对我国昆虫化学生态学的发展也能作出一定的贡献。

本书的出版得到国家茶叶产业技术体系和中国农业科学院茶叶研究所及所长杨亚军研究员的支持,上海科学技术出版社和周星娣编辑为本书的出版予以积极支持并做了大量的工作,使之能够顺利出版。在此表示衷心的感谢。由于时间仓促,本书必然会有错误和遗漏之处,殷切希望读者和同行在阅读过程中提出批评指正。

陳金樞

2012年6月于杭州

Forward

Insect chemical ecology is a branch of Entomology that focuses on the intraspecific or interspecific chemical communication between insects and interactions of insect with other organisms, probes into the role and function of chemical signals in host searching behavior, life and propagation of insect, and the field of cooperative evolution of secondary metabolites of plants, is one of the most active branches in the field of international entomology and chemical ecology. In the recent half century, the development of insect ecology was intersected and fused with the disciplines of biochemistry, molecular biology, ecology, plant physiology, insect physiology, microbiology, electro-physiology, behavioral science, landscape ecology and environmental science etc. The intersections and fusion of various disciplines were the important factor in the social prosperity and development in the past century; it reflected the progress and rationalization of scientific idea. Chemistry is an ancient subject, many achievements emerged from the chemistry changed the life of humanbeing. For example, the discovery of chemical fertilizer in 1843 increased the output of crops significantly. The achievement of chemical pesticides in 1938 controlled the harmful organisms and ensured the bumper harvest of agriculture. However, the over application of chemical fertilizers and pesticides brought about the unexpected consequences, such as severe contamination of environment, pesticide residues remaining on agricultural products, resistance to

pesticides and the resurgence of harmful organisms. It can be attributed to the lack of the idea that related with the ecology in the development of chemical subject at that time, but not the fault of chemical subject. In 1962, a monograph named "Silent Spring" was published by Rachal Carson, who is an American marine biologist. In this book, she described a possible future consequence by using the scientific prediction. The publication of this monograph could be regarded as the prelude of chemical ecology. The coming out of chemical ecology realized the intersection of chemistry and ecology, made the chemistry subject armed with the idea of ecology, and become a new discipline with novel thinking and active in the field of natural science.

The discovery of the first insect sex pheromone symbolized the coming out of chemical ecology in 1959, however, the investigation in chemical ecology was gradually developing in depth, and the research field was gradually broader and broader. The investigation was started from sex pheromone in the very early period, and extended to allelopathy between organisms, insect pheromones and behavior, the indirect resistance function of insect induced plant volatiles, intraspecific or interspecific chemical communications and chemosensory, insect chemical signalings, population regulation and some other research fields as well. The macroscopic depth of the investigation level was developed from the individual level to the population, community and ecological system, the microscopic depth of investigation was developed from the individual to molecular level and genome level.

Tea grown in the temperate zone, subtropical zone and tropical zone in China, and the insect pests were occurred all over the year. The over-application of pesticides was not only induced the pesticide residue problem, but also occurred these problems including the resistance of insect pests to pesticides and the resurgence of secondary pests etc. Tea is a beverage beneficial to human health. So, the planters expect to conduct the Green Control System by using the innocent management methods, in order to get a kind of non-polluted healthy drink. Based on

this background, my research group started to conduct the investigation and probed into the chemical ecology of tea pests since the nineties of 20th Century. During the period of more than 10 years, the researches were supported by the National Natural Science Foundation, Modern Agro-industry Technology Research System (CARS), National Sci-Tech Sustaining Plan, Public Welfare Industry Scientific Item, Important Item of Scientific and Technological Bureau of Zhejiang Province, Natural Scientific Foundation of Zhejiang Province etc. Some achievements were obtained in the investigations on the fingerprint of volatiles induced by tea pests, the formation and dynamic changes of volatiles in tea ecological system and the function of ecological regulation on the tea pests population. Although there were some monographs on the insect chemical ecology published in China, however, they were mainly related to the basic theory on the chemical ecology. This monograph is focused on the tea plant, and discusses the chemical communication between tea pests and tea plants. The contents of this monograph are mainly selected from the investigation in our research group. Besides, the historical information and some achievements from other countries were also collected for the purpose of the integrity of information. This book will provide some references on the chemical ecology of insect pests theoretically; it will also provide some new ideas on the innocent management of tea pests. It was expected that the publication of this book will improve and promote the green control of harmful organisms in tea industry based on the theoretical and practical investigation, and also make some contributions on the development of insect chemical ecology in China.

This book is supported by Modern Agro-industry Technology Research System (CARS) and Tea Research Institute of Chinese Academy of Agricultural Sciences (TRICAAS). Professor Yajun Yang, who is superintendent of TRICAAS and scientist in chief of CARS in Tea industry, give us much courage and help during writing. We are much appreciated for the great support from Prof. Xindi Zhou of

Shanghai Scientific and Technological Publisher in the edition and hard work on this book. Due to the time limit, of course, there were some mistakes and omissions appeared in this book, we hope the readers and experts give us some criticism and ideas during the reviewing process.

Zongmao CHEN

August 2012, Hangzhou

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