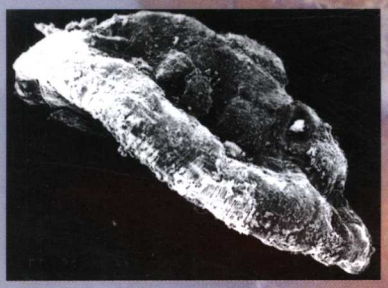
蚧科昆虫的蜡泌物
超微结构和化学成分

Wax Secretions of Soft Scale Insects
Their Ultrastructure & Chemical Composition



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内容提要

本书是研究蚧虫蜡泌物的专著。全书共分6章，重点介绍作者近年来采用扫描电镜、红外光谱、气－质联用等技术对我国蚧科昆虫蜡泌物的研究成果。内容包括：蚧虫的分类概况和蚧科的分类系统；国内外对蚧虫蜡泌物的研究；蚧科内6亚科17种代表蚧虫的生物学、形态发育、泌蜡腺体变化、蜡壳的形成过程、蜡泌物的超微结构、红外光谱特征、化学成分。通过研究，发现了不同种属的蚧虫在不同的发育阶段及雌雄性之间蜡泌物的分泌特点和变化规律，将蜡泌物红外光谱的谱带归为6种谱带型，共检测确定了蜡泌物化学成分的104种组分，明确了蜡泌物的超微结构与其红外光谱特征和化学成分之间具有内在的联系和系统学意义。这为研制防治蚧虫新型高效杀虫剂，突破防治蚧虫的困难；利用蜡泌物的化学成分作为信息素，利用天敌和病原菌开展蚧虫生物防治；将蜡泌物作为新性状开展蚧虫化学分类和系统学研究，以及开展蚧虫蜡泌物的生物资源利用等方面都提供了新的思路和重要依据。

本书内容主要是作者的第一手研究资料和最新的研究成果，同时吸收和总结了国内外的相关知识，提供的资料和数据十分丰富，包括虫种选择、采样方法、材料的预处理和试验方法与步骤等。文中附有表格24个，蚧虫形态特征绘图28幅，生态照片41张，蜡泌物的超微结构扫描电镜照片142张，红外光谱图23幅，色谱图21幅，蜡泌物的104种化学成分结构式。为了便于对外交流，所有表格和图片说明均为中英文对照。

本书多学科知识交叉，知识层次由浅入深，图文并茂，学术性、理论性与实用性并举，适用范围广，可读性强，是反映我国和世界蚧虫蜡泌物研究最新水平的一部著作。可供农林植物保护、昆虫学、生物科学、有机化学、农药化工等方面的高等院校、科研单位、技术管理和生产部门参考。

OUTLINE

This book is a monograph on wax secretion of the scale insects. It is made up of 6 chapters and the emphases are on the research results in the wax secretion of the scale insects in the family of Coccidae (Hemiptera: Coccoidea) by using the scanning electron microscope (SEM), infrared spectrum (IR) and gas chromatograph / mass spectrometry (GC/MS) by the authors in recent years. The contents include the classification introduction of the superfamily, Coccoidea and the classification systems of the family, Coccidae, the research situation on the wax secretion of scale insects in the world, the biology, morphological development, various wax glands, the form of the wax tests or wax covering, the ultrastructure, infrared spectrum characteristic and the chemical composition of the scale insects of 17 species in 6 subfamilies of Coccidae. The wax secreting characteristics and varieties are found among the species and genera and with their developmental stages and the sex of the scale insects. The infrared spectrum characteristics of the wax secretions are divided into 6 kinds. 104 compounds are determined from the test wax secretions. The natural relationship and systematic significance are showed between the ultrastructure, infrared spectrum characteristic and the chemical composition of the wax secretion. Based on the results, some new ideas and references will be given for developing the new and effective pesticides to control the scale insects, for using the chemical compositions as semichemicals to biological control scale insects by natural enemies, for developing chemical classification and systematics in the scale insect study, and for exploiting the wax of scale insects as biological resources.

Most of the information in this monograph are from the first – hand material and the research achievements of the present authors. Some relative new knowledge is also collected from the world. Abundant data and information are included such as the species of scale insects, sample collection method, experiment material treatment and test procedures, 24 tables, 28 morphological figures, 41 ecological and morphological photos, 142 scanning electron microscope photos, 23 infrared spectrograms and 21 gas chromatograms, the chemical structural formula of the 104 compounds of the wax secretion. For exchanging easily, the explanations for all of the tables, figures and photos are give in both Chinese and English.

The characteristics of this monograph are knowledge – cross in different scientific fields, from the elementary to the profound, both excellent pictures and texts, academic and theory combining with practice use, wide application, interesting reading. It reflects the current research level on the wax secretion of scale insects both in China and the world. It is very useful and an important reference book for the students, researchers, officials and workers who are going for agricultural and forestry plant protection, entomology, life science, organic chemistry, pesticide chemistry and industry.

致　谢

在本书完成之际，我首先向我的恩师汤枋德先生表示由衷的感谢，感谢他将我引入蚧虫学这一非常有趣又在科学上很有意义的领域，感谢他对我多年的培养。就在2004年夏天，他临终住院期间还对我的工作和我国的蚧虫研究给予鼓励，这将激励我不断前进。特别感谢我的博士导师郑乐怡先生，正是导师渊博的学识、严谨的治学作风和科学上的创新精神，给予我在昆虫学与化学两个学科的交叉领域开展研究的勇气。

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我还要特别感谢国际蚧虫学专家，美国农业部昆虫系统学实验室 Douglas Miller 教授和 Maren Gimpel 博士；美国弗吉尼亚大学 Michael Kosztarab 教授；美国加州大学戴维斯学院 Peeny Gullan 教授；以色列农业研究组织昆虫学部 Yair Ben-Dov 教授；英国蚧虫学家 Chris J. Hodgson 教授；意大利 Padua 大学农学院 Giuseppina Pellizzari 教授；土耳其植物保护研究所 Lerzan Erkilic 博士。

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谢映平

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前　言

蚧虫是蚧总科 Coccoidea 昆虫的总称，在分类上属昆虫纲 Insecta 半翅目 Hemiptera 中的同翅类 Homoptera，全世界记录约 7000 种，分属于 22 科，其中蚧科 Coccidae 约 144 属 1088 种，是仅次于盾蚧科 Diaspididae 和粉蚧科 Pseudococcidae 的第三大科（Ben－Dov，1993）。蚧科昆虫又称软蚧，英文为 soft scale insects。我国蚧虫已知近 700 种，其中蚧科昆虫 39 属 83 种（汤，1991）。除了白蜡虫（蚧科）和紫胶虫（胶蚧科）的蜡泌物作为生物资源早被人工开发应用外，其余大多数种类均是世界范围农林业的重大害虫。

蚧虫的最大特点是虫体具有多种腺体，能分泌蜡质，蚧科昆虫的泌蜡量在蚧总科中属最大的一类，其蜡质重量可占到虫体总重量的 58% ~98%，在虫体表面能形成厚蜡壳。由于蜡壳的保护，蚧虫对外界不利条件的干扰具有很强的抵御能力，使天敌捕食和病原物入侵受到障碍。由于药剂不能渗透蜡壳，使防治很难奏效。特别在现代，随着全球气候反常，生态恶化，环境污染加剧，蚧虫的抗逆性强、繁殖力大、成活率高的生存优势表现得更加突出，它们已上升为农林、果树、花卉等产业的主要害虫，甚至达到毁灭性的程度。如枣树和柿树上的日本龟蜡蚧、柑橘上的红蜡蚧，城市园林树木上的瘤大球坚蚧等，都是著名的例子。但是，直到目前，蚧虫防治仍多沿用一般害虫的防治方法，以常规有机磷和菊酯类杀虫剂喷雾为主。由于蚧虫一生主要隐蔽在蜡壳内生活，喷雾的杀虫剂不能很好地粘着、渗入蜡壳内和接触虫体，起不到防治效果，反而大量杀伤天敌，引起环境污染，导致蚧虫危害更加猖獗。更重要的是，蚧虫分泌蜡质和形成介壳是一个生命活动过程，在不同发育阶段，蜡泌物的细微结构和化学成分呈现一定的变化特征，常规杀虫剂从物理形状和化学性质上对蜡泌物的这些变化特点缺乏针对性，因此，在防治上一直难以取得突破。同样，由于蜡泌物结构和化学气味等成分的变化，影响天敌昆虫的寄生和捕食行为，使生物防治受到限制。前人虽然在生物防治方面做了不少努力，但目前对蚧虫天敌的利用仍处于基本资源调查和简单的人工引进、助迁和释放。关于天敌昆虫的有效性与蚧虫蜡泌物关系的

研究很少，但这却是筛选有效天敌、开展生物防治的一个关键问题。系统研究蚧科昆虫蜡泌物的超微结构和化学成分及其变化规律，能为研制新型高效杀虫剂和有效利用天敌，开展生物防治两方面提供新的理论依据和实践思路。

虽然科学界很早就对蚧虫蜡泌物给予关注，并在20世纪前期做了不少观察和研究工作，其中Kohno等人对蜡蚧蜡泌物的化学研究是比较好的代表。但对蜡泌物的超微结构和化学成分研究是从20世纪中叶以后，随着电子显微镜和现代化学分析仪器的出现才真正开始。研究较好的有日本的昆虫学家Kawai和Tamaki（1967，1968，1971）对分布于日本的蜡蚧如伪角蜡蚧*Ceroplastes pseudocerferus*，日本龟蜡蚧*C. japonicus*和红蜡蚧*C. rubens*的系列研究和80年代Hashimoto对珠蚧科草履蚧及其他几种蚧虫的研究；法国Foldi在蚧总科范围内对泌蜡腺体的超微形态的比较研究；澳大利亚对几种蜡蚧的蜡泌物化学成分的研究，以及美国、新西兰和其他一些国家的研究人员对柑橘上个别蚧虫蜡泌物做过的零星研究。这些都为继续研究蚧虫蜡泌物的超微结构和化学成分提供了重要基础。

综观世界研究，目前还存在5方面问题，① 虫种数量较少，截至目前仅涉及蚧科昆虫10种，与该科1088种相比，还不到1%。研究虫种零散而没有规律，缺乏系统性。② 没有将蜡质超微结构和化学成分很好地联系起来，往往是某一研究者只做某一虫种的蜡壳结构观察，而另一研究者则只做蜡泌物化学成分测试，对结果的分析相对肤浅。③ 大多只选择雌成虫一个虫态作为研究材料，对雄性和若虫期的不同虫龄很少应用，使研究结果的利用具有很大局限。④ 蜡泌物与杀虫剂研制及蜡泌物与天敌昆虫搜索寄主行为之间的相关性研究很少。⑤ 研究方法上从未运用红外光谱技术。

我国尽管在开发利用白蜡虫和紫胶虫蜡泌物的历史可以追溯到13世纪，且现在仍有中国林业科学研究院资源昆虫研究所在坚持这方面的工作，但在研究蚧害类群方面，以往主要集中在区系调查、生物学、生态学及一般防治应用，蜡泌物的超微结构和化学成分在以前尚未开展研究，处于空白。我从1985年读研究生期间，师从著名蚧虫专家汤枋德教授，开始了对蚧虫的研究，硕士论文题目是“中国蜡蚧属*Ceroplastes*的研究”，此后坚持不懈，先后主持和完成数项蚧虫研究课题，包括“山西省蚧害考察及防治研究”、“城市污染对太原市园林蚧虫发生的影响及防治研究”、“毁林新害虫花椒绵粉蚧的暴发及防治研究”和“泡桐丰产林桑白蚧的发生与防治”等。受山西省林业厅的支持，从1990年起，曾用几年时间对山西省的林木果树蚧虫进行了全面考察和重点研究。1998年，我编著的《山西林果蚧虫》一书由

中国林业出版社出版。

同年秋我有幸考入南开大学，师从昆虫分类学家郑乐怡教授攻读博士学位，继续进行蚧虫学的研究，并将“中国蚧科昆虫蜡泌物及其系统学意义研究”作为博士论文题目，在这一领域开展探索。2002 我得到国家自然科学基金资助，项目名称是“中国蚧科昆虫蜡泌物的超微结构和化学成分研究”。为了完成学位论文和科研项目，我数次专程赴四川、云南、海南、广东、湖南、上海、浙江及南京等地采集标本和考察蚧虫，并在山西、河北等地设立试验地进行了定点定期的观察研究。实验室工作主要包括蚧虫标本处理、玻片标本制作、虫种鉴定、蚧虫蜡泌物扫描电镜观察前的处理和化验分析前的收集和预处理、蜡泌物形态结构的扫描电镜观察、摄影、图片处理和结果分析、蜡泌物的红外光谱分析和气相色谱—质谱联用仪分析，分析图谱解析和化学成分确定。2004 年 4 月，第 10 次国际蚧虫学大会（The 10th International Symposium on Scale Insect Studies）在土耳其的阿达纳市召开，我在会上报告了我们在蚧虫蜡泌物方面的研究进展，受到国际同行的赞扬。“朝鲜毛球蚧蜡泌物的化学成分研究”（The Chemical Composition of The Waxes Secreted by A Scale Insect, *Didesmococcus koreanus* Borchsenius）和“四种蜡蚧蜡泌物的红外光谱及其在系统学上的意义”（The infrared spectra of the wax secretions of the four wax scales and its significance in systematics）两篇论文收录在大会论文集中。

目前，本作者撰写和发表蚧虫蜡泌物研究论文 13 篇。本书就是在总结我们最近几年研究结果基础上完成的，书中内容绝大多数都是作者的第一手研究资料。全书共分 6 章，包括蚧虫蜡泌物研究概况、蚧虫蜡泌物超微结构研究、蚧虫蜡泌物的红外光谱特征研究、蚧虫蜡泌物化学成分研究、蚧虫蜡泌物研究结果与相关问题讨论、蚧虫蜡泌物化学成分的分子结构式和参考文献。重点突出蚧科在我国分布的代表性种类，计 4 亚科 15 属 17 种，系统研究了它们的生物学特性、雌雄性别之间和不同发育龄期的形态学特征和泌蜡腺体的变化、蜡泌物的超微结构和蜡壳的形成、蜡泌物的红外光谱特征和化学成分。在此基础上，将蜡泌物划分为 6 种类型，以蜡泌物的变化特征作为新性状，对目前蚧科昆虫的两个代表性分类系统即汤氏分类系统和 Hodgson 分类系统进行了对比讨论，对两个分类系统中科下分类单元的划分提出自己的看法，对朝鲜毛球蚧等虫种的分类地位提出了新的建议，这在蚧虫化学分类和系统学研究上很有意义。

根据蜡泌物化学组成，我们发现蜡泌物组分中烃类物质包括长链烃类和环烃类化合物是限制常规化学杀虫剂渗透蜡壳的主要原因，这些烃类化合物

在常规状态下只能被有机氯化合物如苯、氯仿等或氢氧化钠、氢氧化钾等强碱类化合物所溶解，但是，这些化合物的毒性或腐蚀性太大，在杀虫剂中不能作为渗透剂应用，由此指出了目前针对防治蚧虫类的化学杀虫剂研制的主要困难。这对未来研制新型杀虫剂中试验筛选其主剂和辅助剂材料，使其在物理性状上与蜡泌物的超微结构更易嵌合，在化学性质上与蜡泌物更易融合，其中最重要的是创新杀虫剂渗透剂的分子结构，使其既能提高杀虫剂对蜡泌物的附着力和渗透性，又对环境和植物无毒无害，对实现蚧害防治的突破将具有重大意义。

在蜡泌物中包含有多种萜烯类化合物，从生物学功能上分析，其中部分萜烯类可能以化学信使的角色存在，在天敌昆虫寄生或捕食蚧虫过程中的搜索行为具有招引和导向作用，这对深入认识蜡泌物在蚧虫与天敌昆虫之间的化学联系，发挥其在生物防治中的作用是一个新的启发。蜡泌物中包含多种长链脂肪酸和脂肪醇，其中一些已经发现可能对病原菌具有抑制作用，这对从理论上解释自然界中蚧虫很少感染病原菌提供了依据，也为研究利用病原菌防治蚧虫提供了新思路。

蜡泌物中还包含有妊娠环和雄甾烷酮类化合物，反映出蜡泌物的分泌与蚧虫的发育、性成熟、雌雄交配和繁殖可能相关。蜡泌物的超微形态和化学组分不仅在不同的属种之间具有明显不同，在同种的雌雄性别之间和不同的发育龄期之间也有差别，这使我们认识到蚧虫分泌蜡质并不像以前所认识的仅仅是一种次生代谢产物，它不仅是蚧虫体壁表面一个物理障碍和保护层，而且可能具有多种生物学功能，是蚧虫整个生命活动中的一个重要组成部分。像对待白蜡虫、紫胶虫和胭脂蚧那样，利用蚧虫蜡泌物作为生物资源是科学家非常感兴趣的事情，我们的研究结果可能对这方面的探索会有裨益。综上所述，我们相信选择蚧科昆虫作为研究对象，对整个蚧总科的蜡泌物研究具有典型性和示范作用，同时也会对研究同翅类或其他具有泌蜡特性的昆虫起辐射和启发效应。

本书虽然包括有我们已经发表的论文内容，但论文受到篇幅限制，且均以单个虫种的形式分别发表，对种属间蜡泌物形态特征，红外光谱和化学成分的相互比较和对蚧科蜡泌物的全面理解造成困难。本书克服了单篇论文之不足，并有相当篇幅的材料是未曾发表的新内容，同时还收集了其他国家的相关研究资料。因此，它不仅代表了我国在该领域的最新研究成果，而且也反映了世界在该领域的研究进展。

本书提供的资料和数据十分丰富，包括虫种选择、采样方法、材料的预处理和试验方法与步骤等。文中附有表格 24 个，蚧虫形态特征绘图 28 幅，

生态照片41张，蜡泌物的超微结构扫描电镜照片142张，红外光谱图23幅，色谱图21幅，蜡泌物的104种化学成分结构式。为了便于对外交流，所有表格和图片说明均为中英文对照。

本书内容的研究虽历经7年，但真正动笔成书仍显十分仓促，很多内容的取舍和处理上存在困难，特别是本书内容涉及蚧虫形态学、生物学、蜡泌物的超微结构和化学研究，需要几方面的知识，特别是有机化学和分析化学的知识。尽管课题组做出了很大努力，但错误和疏漏之处难免，望读者指正。此书虽然出版，但这方面的研究却刚刚开始，我们的实验室也正在继续这方面的研究，此书旨在抛砖引玉，寄希望更多的研究者加入，期待更多的成果出现。

谢映平

2006年6月

PREFACE

The scale insects are a general call for the insects in the superfamily of Coccoidea. They belong to the order, Hemiptera (or Homoptera) in the class of Insecta. About 7000 species have been recorded in the world and they are classified into 22 families. Coccidae with 1088 species ranked into 144 genera is the third largest family in Coccoidea and just follows the families Diaspididae and Pseudococcidae according to the numbers of the species (Ben – Dov, 1993). In China, near 700 species of scale insects have been recorded, of which some 83 species, 39genera belong to the family of Coccidae (Tang, 1991). Except the pela wax scale, *Ericerus pela* (Chvannes) (Coccidae) and lac insects (Lacciferidae or Tachardiidae) have been developed and used as the beneficial insects for using their wax productions, the most of the rest species have been dealt with as important insect pests for agriculture, forest, horticulture and ornamental plants all over the world.

The most important characteristic of the scale insects is the body with many kinds of wax glands that enable to secrete wax substances. Soft scale insects secrete wax most in Coccoidea. The wax matter secreted by a scale insect can take up 58%—98% of the total weigh of the body and can compose a thick wax test or cover on the scale body surface. The scale insects with wax test can protect themselves well from the attack of unfavorable factors, such as weather, natural enemies and disease bacterial. Due to the wax covering the pesticides can be non – effective for controlling the scale insects. Especially, in modern time, with a unusual global climate, ecological condition and environment pollution, scale insects show stronger life predominance such as the resistant to unfavorable live conditions, a greater reproduction power and less mortality. They have become into one group of the most important insect pests in agriculture, forests, fruit trees, and ornamental flower industry. Even some species have leaded to an industry ruin. The scale insects *Ceroplastes japonicus* Green on jujube and persimmon trees in north China, *Ceroplastes rubens* Maskell on citrus in south China, *Eulecanium gigantea* Shinji on ornamental plant in urban environment are the well – known example. Unfortunately, up to present, controlling scale insects has been using the ordinary methods in which to spray the organic phosphorus and pyrethrin pesticides is the major one. For the scale insects living inside wax tests, pesticides can not adhere on and permeate into the wax tests to contact with the derm of the body and the sprays often unable to play a good part furthermore kill much more natural enemies, result in environment pollution and the scale insects occur in a large scale. A more

important issue is that the secreting wax substances and forming wax tests are a part of the life process of the scale insects. With the scale insects developing in different phases, the morphological fine structures and chemical compositions show different characteristics. But the common pesticides have lacked the associated dealing with these various of the wax secretions. Therefore, it can not obtain a better achievement in controlling the scale insects.

In the similar way, the chemical compositions and volatile gas of the wax secretions also affect the natural enemy's behavior in parasite and prey on scale insects. This limited the effective biological control. Although much more efforts have been taken in biological control, up to today, using natural enemies to control scale insects still are investigation, introduction and release. Rare work was focused on the relationship between the characteristics of the wax secretions of the scale insects and effectiveness of the natural enemies. This work, however, is a key issue for selecting effective natural enemies and developing biological control. To research the changes of the fine morphological structures and chemical compositions of the wax secretions of soft scale insects can be able to provide theory information and practice idea for both developing some special higher effective pesticides and developing biological control.

Although scientists paid more attentions to the wax secretions of the scale insects many years ago, and they indeed did some observation and research in this field in early 20 century, such as the researches carried out by Kohno chemical studies on the wax secretions of the several wax scales, the further researches started in the middle time of the century with the electron microscopy and modern chemical analysis instrument have been available. Some wonderful researches have been done, such as Japanese scientists Kawai, Tamaki and others from 1960s to 1970s had done a series of researches on wax secretions of the wax scales *Ceroplastes pseudoceriferus*, *C. japonicus* and *C . rubens*. Hashimoto worked on scanning electron microscopic observation and some chemical compositions of waxy substances of the species *Drosicha corpulenta* Kuwana (Margarodidae) and other scale insects; French scientist Foldi has studied the ultra – structure of the wax substances of some scale insects; A laboratory in Australia had a series of studies on the chemistry of the wax test secreted by some wax scales; Some researches have been carried out in America, New Zealand and some other countries. These previous works provide a very important base for the further research in this area. In spit of the above works, there are five problems in the researches. First of all, too few species have been involved. Only 10 or more species have been studied in the family of Coccidae before our studies. These species are less 1% in Coccidae that is with 1008 species. The species election lacks the systimatics. The second one, without a good line between the two researches on the ultra – structure and chemical composition of the wax secretions. It is common that some researcher just focused on morphological structure of the wax test of some individual species while other workers just paid their attentions to the chemical composition of the wax secretion of some other species. For this reason the results unable to be analyzed deeply. The third one, in many cases, only adult female was chosen as the research material and the male and nymphs were rarely chosen for the wax secretion studies that limited the effective use for the research information. The fourth one,

the relativity researches were not developed between the wax secretion morphological structure and chemical composition with new pesticide development and natural enemies' behavior in search scale insects. The last one, some analysis methods are still not applied such as the infrared spectra and others.

Although The develop and use of the wax productions secreted by the pela wax scale and lac insects can be traced back to the 13 century in China and even some researches have been carried out in the Institute for the Resource Insect of the Forestry Academy of China, the previous researches on the scale insect pests focused on the fauna investigation, biology, ecology and ordinary control. The ultra – structure and chemical composition of the wax secretions were not researched in China. I started to study the scale insects in 1985 when I was studying for my Master degree under the guide of professor Tang Fangde, an excellent coccidologist. The title of my Master degree thesis was "The study on the genus of *Ceroplastes* in China". Since then I have persisted in this field and have taken over a series of project on scale insect studies including "The investigation on the scale insect in Shanxi Province and their control", "The urban pollution effects on the occur of the scale insects and their control in Taiyuan City", "A study on the new destructive mealybug, *Phenacoccus azaleae*, in the forest of Chinese prickly ash in north China" and "The outbreak and control of the white peach scale in paulownia forest along the Yellow river coast". In 1990, I was supported by the Forest Department of Shanxi Province and spent three years for investigating the scale insects of forests and fruit trees within the province. In 1998, the book "*The scale insects of forest and fruit trees in Shanxi of China*" written by me was published by China forestry publishing house.

In the autumn of the same year, I entered Nankai University fortunately to study for my doctor's degree under the guide of professor Zheng Leyi, an outstanding entomological taxonomist. My doctoral dissertation is "The waxy secretions of Coccidae and its significance in systematics". After graduated I got a financial support from the national natural science fund of China and the project is "The study on the ultrastructure and composition of the wax secretion of Coccidae in China". For completing my doctoral dissertation and the projects I once went to south China several times to investigate and collect the scale insects and I also set up some experimental points in north region, such as Shanxi and Hebei Provinces for investigating in a longer period. The works in the laboratory mainly included dealing with the samples, preparation the slide – mounted specimens, identification of the species; Preparation the test materials for the observation under scanning electron microscope and chemical analysis, the observation, photography and dealing with the photos and results; the test through the infrared spectra (IS) and gas chromatography / mass spectrometry (GC/MS), analyze the spectrum pictures and identifying the compounds included in the wax substances. In April of 2004, the 10th International Symposium on Scale Insect Studies was held at Adana of turkey. I reported our researching work on the wax secretions that was praised by the international colleagues. Our two papers "*The Chemical Composition of The Waxes Secreted by A Scale Insect, Didesmococcus koreanus* Borchsenius" and "*The infrared spectra of the wax secretions of the four wax scales and its*

significance in systematics" were published in the Proceedings of the symposium.

Up to now, our 13 papers have been published on this topic. This monograph is mainly based on our research achievements in recent years and its most of the contents are the firsthand material. The book composed of six chapters namely the introduction, the ultrastructure, the infrared spectra characteristics, the chemical composition, molecular formula of the wax secretion, Some representative species in Coccidae in China are introduced as the key points in this book including 17 species in 15 genera of 4 subfamilies (according to Tang's classification system). The contents include these scale insects biology, morphology and wax glands of the male and female in the nymph and adult stages, the ultra – structure of the wax secretions and wax tests, the infrared spectrum characteristics and chemical compositions. The wax secretions were divided into six kinds basing on the research result. Taking the wax secretion as characteristic we discussed the two classification systems of Tang's (1991) and Hodgson's (1994) for Coccidae, gave some opinion on the rank of groups in subfamilies and gave some suggestions on the classification place of the soft scale insect, such as *Didesmococcus koreanus* Borchsenius and so on. These are significant in the chemical classification and systematics of the scale insects.

According to the composition of the wax secretions, alkanes including long chain and cyclic alkane components in wax secretions are the major factor that limit the pesticides to permeate the wax test. These alkanes can usually be dissolved only by organic chlorine compounds, such as benzene, chloroform, etc. and strong alkali, such as NaOH and KOH. But theses compounds do not to be used as penetrating fluid in the pesticides due to their toxicity or caustic. Through this the hard point can be found in present pesticides development for controlling the scale insects. It is significant for selecting toxicity compounds and assistant material in developing new pesticides so that which are easily to combine with the wax secretions in physical nature and are easily to mix with wax in chemical nature. Even more to innovate the molecular structure of the penetrating agents in the pesticides promotes the adhere capability and permeability for realizing the effective control the scale insects with friendship and non – toxic and unharmful to plants and environment.

Some terpene compounds in wax secretions may play a role as hemichemicals to guide or call the natural enemies to parasite or prey the scale insects. It is a new enlightenment for understanding the connection between natural enemies and scale insects and applying it in biocontrol. Many fatty acids and fatty alcohols are found in wax components and some of them may inhibit the pathogen of the scale insects. This can give out an explanation for why there is a few pathogens to infest the scale insects in the nature. It also offers a new ideal to deal with the resistance from the wax in using the entomopathogenic fungi as a biocontrol agent.

Some compounds such as 5a-Pregn-16-en-20-one, 3a, 12a-dihydroxy-, diacetate, Androstan-17-one,3-ethyl-3-hydroxy-are found in wax secretion. They might inferred the relation with development, sexual maturity, mating, reproduction of the scale insects. Further more, that the ultra – structures and chemical compositions are various with the genus and species and even with sex and develop stage in some species leads to a conclusion that the wax secretion

might not be a secondary metabolism production only as it was understood before. It might be not only a physical obstacle and protected layer but also with many biological functions and an important part of the all process in scale insect's life; Using wax material as natural resources like that of the pela wax scale and lac insect is an interesting topic for scientists. Our research results may be of benefit for the this field. As mentioned, we believe that taking the family of Coccidae as research material can demonstrate with typical example not only for the super family Coccoidea but also for Homoptera and other insect group with wax secretion.

Although this book includes some contents published as papers by us recently, as we know, the articles in magazine limited to its length and the paper's contents usually including only individual species. And that resulted in the difficult to understand completely the all information on morphology, infrared spectra and chemical compositions from the species and genera researched. This book can be able to overcome the shortage of the single article and includes a lot of new information. Meantime, some foreign information on this topic also was taken in. Therefore, this book not only introduces the achievements of China but also reflects the advancement of the world in this field in some degree.

Abundant data and information are included in this monograph such as the species of scale insects, sample collection method, experiment material treatment and test procedures, 24 tables, 28 morphological figures, 41 ecological and morphological photos, 142 scanning electron microscope photos, 23 infrared spectrograms and 21 gas chromatograms, the chemical structural formula of the 104 compounds of the wax secretion. For exchanging easily, the explanations for all of the tables, figures and photos are give in both Chinese and English.

Although the relative works have been done for seven years it is still not enough for completing this book. It is difficult to determine and arrange some contents because the knowledge is involved in the book in several fields, such as morphology, biology, ultra – structure and chemistry, especially organic and analytic chemistry. In spite of the great efforts were made, the mistakes and errors must exist in the book and we welcome the guides from the readers. Although the book is published the researches are just beginning and our laboratory is doing some work in this field. The aim of this book is to throw away a brick in order to get a gem and to induce more workers to come forward with their valuable contributions.

Xie Yingping
June, 2006

若虫夏季在叶部危害，蜡壳为星芒状

The young nymphs settled on the leaves of the host plant in summer and with a waxy cover or test star shaped

雌成虫在枝条上危害，蜡壳为龟背状

Adult females settled on the branches or twigs of the host plant in winter and the following spring. The thick waxy test is in tortoise shell shape

雌成虫腹面观，示胸气门路五格腺分泌的蜡质形成白色蜡带；卵产在腹面

Adult females in ventral view show the two pairs of white wax bands secreted by the quinquelocular disc-pores along the thorax stigmatic furrows. The eggs deposited beneath the ventral surface