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柏广新 吴榜华 等著

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# 中国东北红豆杉研究

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# RESEARCH IN CHINA'S TAXUS CUSPIDATA

Bai Guangxin Wu Banghua

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# 《中国东北红豆杉研究》

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史宝辉

# 序

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随着科学技术的迅猛发展,珍稀的第三纪孑遗树种——东北红豆杉 (*Taxus cuspidata* Sieb. et. Zucc) 因其特殊的药用价值,被誉为“国宝级树种”,成为世界竞相开发的热点,其提取物紫杉醇 (Taxol) 是一复杂的二萜类化合物。美国国立肿瘤研究所所长 Broder 博士称其为“近 15 年来发现的最主要的抗癌新药”。目前,美国、法国、英国、日本等许多国家竭尽全力研究开发紫杉醇及其新类似物,我国也开展了红豆杉及紫杉醇的研究,在临床及药理等方面做了大量的工作。东北红豆杉枝叶浓密苍翠,树姿婆娑优美,是上等的观赏树种,国内外已广泛采用它点缀城市绿地和庭院园林。长白山是东北红豆杉的分布中心,由于其材质优良、纹理通直、结构致密、富有弹性、力学强度高、具光泽、有香气、耐腐朽、不含松脂,适用于乐器、雕刻、高级家具、美工装饰,备受青睐。由于其独特的材性,也带来了厄运,历经长期不合理的掠夺式砍伐,其资源已濒临灭绝。为了恢复其青春,吉林省延边朝鲜族自治州林业管理局开展了大规模的东北红豆杉苗木培育、更新造林和资源保护工作,截至 1999 年,已培育幼树近百万株,计划 10 年营造东北红豆杉人工林 1 000hm<sup>2</sup>,建成东北红豆杉资源培育加工基地,为东北红豆杉的培育和应用奠定坚实的基础。

2000 年,江泽民总书记在国家“星火计划”实施 10 周年总结表彰大会上做出了“要进行一次新的农业科技革命”的重要指示,林业作为国民经济的重要基础产业和社会公益事业,始终处于优化环境、促进发展的关键地位。遵照江泽民总书记指示,扎扎实实地进行林业新科技革命,是实现林业跨越式发展的根本途径和希望所在。只有将林业新科技革命做为推动林业生产力发展的强大动力,才能大幅度提

高林业建设的整体水平，缩短与发达国家的差距，更加充分地显示林业在实现国家经济社会可持续发展中的重要地位和作用。林业新科技革命既不等于农业、工业及其他行业的新科技革命，又与这些行业的新科技革命紧密联系，相互促进。其特殊点在于它的首要任务是改善生态环境，优化生存环境质量；其次是紧密联系可持续发展，特别是它在保护生物多样性方面发挥着不可替代的巨大作用。在长白山区建成高效东北红豆杉林基地绝不是一般的技术问题，它本质上是通过对林业新科技革命保护生物多样性，实现林业跨越式发展的一种形式。

搞好林业新科技革命，是一项长期、细致的工作，必须从大处着眼，小处着手，一步一个脚印地进行。柏广新高级工程师、吴榜华教授充分利用各自工作的有利条件，组织广大林业生产、科研、教学人才，坚持“产、学、研”结合，积极合作著述了《中国东北红豆杉研究》这一专著，系统地研究和介绍了东北红豆杉的地理分布，生物学特征，生态学特性，种群和群落特征，种子解剖构造，组织培养，紫杉醇药的提取，临床应用及开发对策等，资料翔实，内容丰富，结构严谨，文字精练，是当今东北红豆杉研究的新成果。它的出版，为中国东北红豆杉资源基地化、产品系列化、质量标准化增添了新的篇章，对我国东北红豆杉产业持续、健康、稳定发展必将起到积极的推动作用。

国家林业局副局长



2002.8.20.



# FOREWORD

As technology develops, the special medicinal value of *Taxus cuspidata* Sieb. Et. Zucc, survived from the Quaternary Period, has given attention to cultivation. It has been regarded as a tree species of national treasure, with its extract taxol as a complicated diterpene compound. Dr. Broder, head of the U. S. National Cancer Institute has called it “a leading new anti-cancer medicine discovered in the last fifteen years”. Today, America, France, the United Kingdom, Japan and many other countries are making all efforts to develop taxol and similar compounds. China is also doing much research in the clinical and pharmacological studies of *Taxus cuspidata* and taxol. *Taxus cuspidata*, with thick branches and broad leaves, is one of the best ornamental trees and widely used for decorating city greens and gardens all over the world. Changbai Mountains in the northeast of China is a center of distribution. It has the qualities of producing superior wood with fine texture, compact structure, good elasticity and material strength, glossiness, and fragrance, and is anti-decay and free from resin. Consequently, it is especially suitable for musical instruments, engraving, quality furniture, and decoration. Its unique material qualities have also led to disastrous irrational cutting, with its resources being at the verge of extinction. To restore its resources, the Forest Management Bureau of Yanbian, Jilin Province, has cultured, regenerated and protected the species on a large scale. By the end of 1999, approximately one million young trees of *Taxus cuspidata* has been cultured. It is planned that over 600 hm<sup>2</sup> of *Taxus cuspidata* will be planted in ten years' time to set up a base for the cultivation of *Taxus cuspidata* resources.

In 2000, President Jiang Zemin instructed that “a revolution in agricultural technology will be implemented”. With forestry as an important foundation industry and socially beneficial enterprise, it is in the key position of optimizing the environment and promoting development. A down-to-earth revolution in new technology for forestry is crucial for the further development of forestry and its role in the sustainable development of national economy. The revolution is both different from that in agriculture and industry and closely related to them. Its primary task is to improve the ecological environment and optimize the living conditions. It is also closely related to sustainable development, especially in its irreplaceable role in the protection of biodiversity. The establishment of the highly efficient base of *Taxus cuspidata* in the Changbai region is not an ordinary technology issue. It is a method of protecting biodiversity through technological revolution in forestry.

The forestry revolution is a long-term detailed task. It is important to aim high and carry out down-to-earth work. Senior Engineer Bai Guangxin and Professor Wu Banghua’s book is the combined effort of many people in teaching, research and production. It systematically discusses the geographical distribution, biological features, ecological characters, population and community features, anatomical structure of the seeds, tissue culture, the extraction of the taxol, and clinical application and development strategies of *Taxus cuspidata*. Its materials are detailed with rich content, strict structure and refined discourse. The publication of these latest research findings represents a new chapter in the resource base of China’s *Taxus cuspidata*, the serialization of forest products, and the standardization of product qualities. I believe it will serve as promotion for the sustainable production, and healthy and stable development of *Taxus cuspidata*.

Li Yucai

August 20, 2002

# 前 言

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东北红豆杉 (*Taxus cuspidata* Sieb. et. Zucc) 又名紫杉、朱树、赤柏松, 日本称“一位”(意即“一品”), 隶属于红豆杉科 (TAXACEAE) 红豆杉属 (*Taxus*), 是一个珍贵的第三纪孑遗树种。主要分布在长白山、辽宁省东部海拔 500~1 000m 的红松阔叶林内, 半个世纪以前尚有成片大树, 由于其材质优良, 经长期盗伐, 目前已很难找到其踪迹。台湾学者郭宝章 (1993 年) 称其为濒临灭绝的“国宝级”树种。其材质优良, 纹理通直, 结构致密, 富弹性, 力学强度高, 具光泽, 有香气, 耐腐朽, 易刨削, 不易开裂反翘, 不含松脂, 边材幅狭黄白色, 心材紫赤褐色 (紫杉因此而得名)。着色涂漆胶接性能优越, 适用于乐器、雕刻、高级家具、美工装饰等用。除了全株含有紫杉素 (Taxin,  $C_{37}H_{51}NO_{10}$ ) 植物碱外, 还含有剧毒的东北红豆杉精油, 但其假种皮微甜可食。同时, 东北红豆杉的树皮、木屑、种子可提取栲胶原料。东北红豆杉树形优美, 果鲜红色, 其枝叶四季浓密苍翠, 可作为优美的庭园观赏树。东北红豆杉根、茎、叶、树皮均可入药, 叶可通经利尿, 治疗高血压症, 并有抑制糖尿病及治疗心脏病之效。

紫杉醇 (Taxol) 是从红豆杉属植物中分离得到的一种二萜烯类化合物, 是一种新型、高效、广谱抗癌药物, 特别是对卵巢癌、乳腺癌有较好的疗效。但紫杉醇在植物体内含量普遍很低, 红豆杉属植物的树皮中含量约 0.01%, 每提取 1kg 紫杉醇, 要砍伐 1 000~3 000 棵树, 即使将全部资源采尽, 也只能满足短期需要。因此, 紫杉醇价格特别昂贵, 一般患者难于支付。紫杉醇的原料保障已成为该药能否成功走向市场的关键因素。近年来保护红豆杉资源扩大再生途径已经成为学者们的热点课题, 当今世界范围内开发红豆杉资源方兴未艾。

东北红豆杉为珍贵稀有树种，具有广泛的开发利用价值，但其资源濒危，造林技术又长期未得到解决，致使其后继无林的现象十分严重。近来研究发现东北红豆杉的树皮、根、茎、叶等部位含有治疗癌症的紫杉醇，致使形成了开发东北红豆杉资源热。目前，东北红豆杉只见于人迹罕见的森林中，天然资源非常少，为了开发利用这一资源，必须大面积引种驯化，这就要求必须系统地研究东北红豆杉的生物生态学特性、地理分布区及其群落学特征、管理技术等。为了达到此目的，《中国东北红豆杉研究》著作项目组主要成员在 60 年代的研究基础上，先后向国家自然科学基金会、吉林省科技厅、吉林省教育厅等部门申报东北红豆杉资源调查与保护生物学等方面的研究课题，并得到资助。经过项目组人员多年努力和联合攻关，在濒危树种东北红豆杉的研究领域内取得了令人瞩目的成就。

本项研究系统地对我国东北红豆杉的地理分布、群落学与种群特性、育苗造林及抚育经营、资源的开发利用等进行了细致研究。这一研究成果，不仅是我国积极发展东北红豆杉保护生物学的重要成果，而且对开发抗癌物质、造福人类具有重大意义，是一项理论研究与应用开发研究结合的范例。本项研究采用了群落生态调查、定位半定位研究、实验示范和生产推广相结合的方法，并建立东北红豆杉培育基地，为项目进一步发展、应用打下良好的基础。对东北红豆杉全面系统的研究属于首次，对红豆杉的开发利用也首次推向了规模发展的道路。本项研究不仅在国内是领先的，而且在有东北红豆杉分布的其他国家也是没有的。本研究已具有明显的国际影响。

本专著即是根据以上获得的研究成果，由各方面的专家著述而成。全书共分为八章：第一章为东北红豆杉的自然地理分布；第二章为东北红豆杉生物生态学特性；第三章为东北红豆杉种群、群落生态学；第四章为东北红豆杉的森林培育技术；第五章为东北红豆杉的木材构造、物理性能和化学成分；第六章为紫杉醇的开发利用；第七章为延边地区东北红豆杉保护与开发对策；第八章为红豆杉属其他种的相关研究文献。

本专著在国际上首次对珍贵濒危树种东北红豆杉进行了系统综合的研究,首次研究了其生长特性、繁殖规律及其生长的生态环境;首次提出了一整套的人工林培育技术及天然东北红豆杉林的抚育措施,摸清了东北红豆杉的自然地理分布区域及其资源状况,找出了其濒危的原因及开发对策;首次对立地类型进行了划分与评价,确定了建立东北红豆杉基地的适生立地条件,研究确定了东北红豆杉的生物生态学特性,从理论与技术上提出了育苗、种子催芽、田间管理、更新造林、越冬保护等森林培育技术措施,为大面积营造东北红豆杉速生丰产林提供一整套的切实可行的配套技术和理论基础。

本专著在成书过程中,得到了许多领导和专家的大力支持。国家林业局李育才副局长在百忙中为本书作序。在此我们谨对他们表示衷心的感谢。

由于本专著成书时间较紧,又限于著者水平,不妥甚至错误之处在所难免,恳请读者不吝指正。

柏广新 吴榜华

2002年7月30日

## PREFACE

*Taxus cuspidata*, of the family *Taraceae* and genus *Taxus*, is a valuable survivor from the Quaternary Period. It is mainly distributed in the red-pine and broad-leaved forests of Changbai Mountains and east Liaoning Province at the height of 500~1, 000 meters above sea level. Fifty years ago, there were large areas of adult trees, but due to illegal cutting for its superior wood quality it is now difficult even to find its traces. Therefore, it is called by Taiwanese scholar Kuo Paochang (1993) to be “a species of national treasure at the verge of distinction.” It is known for producing superior wood with fine texture, compact structure, good elasticity and material strength, glossiness, and fragrance, and is anti-decay, easy to shape, poor cracking and springing, and free from resin. Its sapwood is yellowish white while the heartwood is dark reddish brown. It has good performance for coloring and painting, thus suitable for making musical instruments, engraving, high-quality furniture and artistic decoration. Apart from the plant alkaloid “taxin ( $C_{37}H_{51}NO_{10}$ )”, it also contains the highly toxic boiled oil. However, its aril is slightly sweet and edible, whereas gum material can be extracted from its bark, chip, and seeds. The tree has elegant shape, scarlet fruit, and thick branch and evergreen leaves. Consequently, it is often used for garden ornament. Its root, stem, leaves and bark can all be used in medicine. The leaves can serve as emmenagogue and diuretic, help curing high blood pressure and heart diseases, and restrain diabetes.

Taxol, a diterpene compound extracted from *Taxus* plants, is a new, efficient, broad spectrum anti-carcinogen, especially effective for

ovary and breast cancers. However, the content of taxol in plants is very small, with 0.01% in the barks of *Taxus* plants. That means that, to extract 1kg of taxol, 1,000~3,000 trees have to be cut. Even if we cut all the existing resources, we can only meet short-term demands. As a result, the price of taxol is very high, beyond the ability of ordinary patients. As the key to the success of the medicine lies in the sufficiency of resources, the protection and regeneration of the *Taxus* resources have become a major topic of research in the world.

As a valuable endangered species, *Taxus cuspidata* faces the danger of extinction. In recent years, the discovery that the anti-carcinogenic taxol is found in its bark, root, stem and leaves has led to a fever of developing *Taxus cuspidata* resources. At present, it is only found in small quantities of natural resources so the only way to develop this resource is to domesticate the species, which makes it necessary to systematically study its biological and ecological features, geographical distribution, community features, and management technology. To achieve this aim, the project group has received funds from the National Science Foundation, Jilin Province Department of Science and Technology, and Jilin Province Department of Education to carry out research in the resource survey and protective biology of *Taxus cuspidata*. The research work is a continuation of the investigation in the 1960s and combined efforts of many disciplines. The achievement deserves attention.

The present research is a systematic study of *Taxus cuspidata* based on detailed work in its geographical distribution, community and population features, seedling and culture management, and resource cultivation. It is not only an important study in protective biology, but also a significant work in developing anti-carcinogenic substance for the benefit of the humankind and an example of combining theoretical research with practical applications. It uses the technology and methods of population ecological investigation, positioning and semi-positioning

studies, experiments and demonstration, and production and extension. Its culture base has laid good foundation for further development and applications. It is the first complete study of *Taxus cuspidata* and pushes the development and cultivation of the species onto the road of scaled production. It is not only a pioneering study in China, but also one in the world.

The book is written by specialists of many fields on the basis of the project findings. It contains eight chapters. Chapter One describes the geographical distribution of *Taxus cuspidata*; Chapter Two outlines the bio-ecological features of *Taxus cuspidata*; Chapter Three is the population and community ecology of *Taxus cuspidata*; Chapter Four provides the silvicultural technology of *Taxus cuspidata*; Chapter Five gives the wood structure, physical properties and chemical constitution of *Taxus cuspidata*; Chapter Six discusses the development and cultivation of taxol; Chapter Seven demonstrates the protection and development strategies of Yanbian region for *Taxus cuspidata*; Chapter Eight is appendixes.

For the first time internationally, the book outlines a systematic study of the endangered species of *Taxus cuspidata*, and describes the properties of its living, breeding and ecology. For the first time it provides a complete set of technology for artificial breeding and nurturing of natural *Taxus cuspidata* forests, a detailed account of its natural geographical distribution and resource situation, and a discussion of the reasons for its extinction and strategies for development. For the first time it gives a division and evaluation of its site types, and defines the suitable conditions for establishing a production base. The study defines the biological and ecological properties of the species and explains the silvicultural measures for seedling, germination, field management, regeneration and winter protection. It thus provides both the theoretical basis and the practical technology for large-scale construction of fast-breeding and high-



yielding forests of *Taxus cuspidata*.

The book is published in the form of a monograph. The authors welcome any comments and criticisms for its errors.

Bai Guangxin, Wu Banghua

July 30, 2002