GAOTONG

膏桐

生物、生态学及其新品种选育技术

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前　言

膏桐（Jatropha curcas *L.*），又名小桐子、小油桐，或麻疯树，是目前国际上颇具竞争力的柴油植物。对于该植物的研究，笔者是在参加长江中上游防护林建设工程时开始的。已开展的项目有：中国科学院方向性项目“柴油植物不同地理种源的收集和评价”、林油一体化生物柴油原料林基地建设科技支撑项目子课题项“西双版纳膏桐良种扩繁和丰产栽培试验示范”、园地合作项目“玉溪地区膏桐良种选育试验示范”。收集了国内、外不同地区的膏桐种源130个，建成种质资源圃30亩，系统收集了不同地理种源生物学特性和主要经济性状，开展了膏桐品种选择和新品种培育的工作。目前，已利用突变体培育出膏桐新品种——皱叶黑膏桐，发现了膏桐种源的多花类群、高油类群。但还需开展相关的区域性试验和抗逆性试验等。

本书是对前期项目的一个总结，一共包括七章。第一章膏桐研究综述，介绍国内外膏桐研究的进展和所取得的成果；第二章膏桐适生环境，介绍膏桐分布区气候、土壤、植被特点以及膏桐适宜发展的地区；第三章膏桐造林技术，介绍膏桐种植的整地、育苗和定植的技术措施。第四章膏桐的生物学习性，介绍膏桐的生物学特性和农艺性状等；第五章膏桐地理种源收集和种质资源圃的建设，介绍不同地理种源的收集和鉴定方法以及国内搞品种资源的现状；第六章膏桐不同地理种源地评价，介绍种源评价方法、不同中原生物学特性和农艺性状的分析结果及类别归属等；第七章膏桐新品种培育，介绍一些膏桐新品种培育的思路、方法以及膏桐新品种培育的最新成果。在编写过程中胡华斌研究员和施捍、孙燕瓷等同志给予的鼎力支持，郑玉龙、唐寿贤、白智林等曾参加部分研究工作，在此一并表示衷心的感谢！

总结前期膏桐不同地理种源的收集和评价以及品种选育和新品种培育的成果，其目的在于适应国内生物柴油产业化发展的需要，为膏桐新种质的创制和良种培育提供基础数据，为膏桐种植业的发展提供技术参考。由于时间比较仓促，文中错漏在所难免，敬请批评指正。

杨成源

2008年10月28日

Biology, Ecology and New Varieties Breeding Techniques of Jatropha curcas L.

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Abstract: Since the oil crisis in the 1970s, a common consensus that oil energy is finite has been reached, which promoted the international society to improve energy technology and exploit renewable energy resources. At the International New Energy Conference in Jakarta, capital of Indonesia in 1980, "Biomass is a new renewable energy" was clearly stated. Many countries started to research and develop biomass energy, and the achievements were rewarding, e. g. biomass power plants in the Philippines and Korea, wood gas in France, etc. China set up firewood forests mainly composed of such fast growing timber tree species as eucalyptus trees, and developed marsh gas, wood gas, biomass briquette fuel, and ethanol fuel, etc. Up to now, ethanol fuel (10%) has been promoted in North and Northeastern China. The promotion of marsh gas in Southwest and Northwestern China has contributed to the solution of energy consumption in rural areas and save up consumption of forest resources, meanwhile protect the ecological environment. With the soaring process of oil in the 21st century, renewable energy resources are attracting a major global attention. Some developed countries have set up *Biomass Energy Standard System*. China enacted *Renewable Energy Law of People's Republic of China*, and the National Development & Reform Commission of China published *Middle and Long - term Program of Renewable Energy Development* as well.

Biomass energy as a substitute source for oil is a new trend in the 21st century and raises new research and development challenges. The Chinese Ministry of Finance is drafting a development goal on the substitute of biomass energy for oil. The development of biodiesel fuel is one of the ways. Preliminary studies on the cultivation of physic nut tree (*Jatropha curcas* L.), especially its drought resistance, has somewhat shown that it can meet the objectives of biodiesel fuel and special profit. *Jatropha curcas* L. can grow well on arid and semi - arid regions and

does not vie with grains for arable lands, which are the advantages attracting the people. Some bioenergy corporations are beginning to focus on the development of *Jatropha curcas* L. Some large state - owned enterprises like SinoPec and SoPec are cooperating with the State Forestry Administration to pour funds into the establishment of cultivation bases of bioenergy plants, in order to get it industrialized. A yield of 5 million tons oil is expected to gain by 2020.

To develop biodiesel well, elite species is a key factor. The aims of developing biodiesel fuel used to be expanding the income sources of farmers and contributing to ease global warming of greenhouse effect through oil plants plantation orientated to oil production. The present aims are not so limited. The industrialization of biodiesel fuel and showing its leading role has become the major target, which requires species of high yield and rich oil content as its basis.

The screening of elite *Jatropha curcas* L. species takes much time, of which collecting plants of different geographical provenances is an essential step. If started from 1600, the development of *Jatropha curcas* L. has a history of over 400 years. The former 300 more years were based on natural resources, using the seeds oil to make soap or of medicinal use. Since the 1930s, *Jatropha curcas* L. came into the phase of developing biodiesel fuel. However, the research of *Jatropha curcas* L. was mainly focused on the processing and utilization of seeds and oil. The screening and breeding of species were relatively weak. Actually, the collecting, screening and breeding of *Jatropha curcas* L. in the world did not start until 1980, even later in China. At present, main attention is focused on the collecting and evaluating of germplasm resources. The selecting of elite species is at the very beginning.

We had collected *Jatropha curcas* L. of different geographical provenances, including Yunnan, Sichuan, Guangxi, Hainan and Guizhou of China, and Laos, India, Vietnam, Thailand, Myanmar, Cambodia, Indonesia, and Suriname as well. Through collecting a specimen every other longitude or latitude, we have got 130 specimens of geographical provenances. By using seeds and twig cuttings, we erected a nursery of 2 ha within Xishuangbanna Tropical Botanical Garden, the Chinese Academy of Sciences. Meanwhile, we had evaluation on the biological and agricultural characteristics of different geographical provenances. The evaluation included diameter, height, and crown growth; leaf, seedling germination, flowering, blossom and bear fruit; colors of fruits and seeds, size, length, weight, and seedling emergence rate, cone rate; styles of inflorescences, sex ratio; oil content, oil extraction rate; measures to breeding *Jatropha curcas* L. seedlings and afforestation.

Our observation made it clear that the growth of *Jatropha curcas* L., within a year, trails on the obstacle curve (S curve). During June and July, *Jatropha curcas* L. is in a period of rapid growth, and a grace period in mid August. Afterwards, a new small prime growth period comes during September and October, and growth stagnancy comes in late October. The biennial seedling plant is at a height of 2.0 meters, 5.0 cm of diameter at ground; whereas the cutting plant is at a height of 2.5 meters and 5.5 cm of diameter at ground. Under suitable conditions, *Jatropha curcas* L. appear buds when spring begins, bloom and set fruit in part in late

March; the first prime period of flowering and fruit setting is in April and May, and the second comes in September and October. The inflorescences of *Jatropha curcas* L. are divided into two groups. One is male inflorescence. i. e. no male flower in the whole inflorescence. The other is mixed inflorescence; the change of sex ratio depends on environment. The two inflorescences alternate with each other. Normally, the flowers of *Jatropha curcas* L. are unisexual (staminate flower or pistilate flower). When in chilly winter or other extreme conditions, some bisexual flowers may appear. For mixed inflorescence, the sex ratio is 12% ~20% of female flower. About 15 g of fruits are harvested, 3.5 cm in vertical diameter and 3.0 cm in transverse diameter, pericarp thickness of 0.55 cm, seed weight of 3.4g, 1.3g of each kernel, seed size of 2.2 ×1.2 ×0.9cm, 44% and 56% of kernel husk ratio respectively. After air dry, the weight of fruits is 3.5g, with 2.8 seeds, cone rate of seeds is 60%, seed size of 1.8 ×1.1 ×0.9cm, 750 g of every 1000 kernels, oil content of 30% ~40%, oil extraction rate of 30% ~33%, pure oil rate of 25% ~28%. In fruiting period, the yield of seeds is 40 ~50 kg/mu. The biomass is 1500kg/mu in the annual *Jatropha curcas* L. forest.

We also found that, on the basis of such economic characteristics as seed weight and oil content, continuous variations occur in different geographical provenances, the differences between close geographical provenances are difficult to detect from macro view. However, when all geographical provenances are planted under the same situation, the distribution of the whole population appears as a triangle, which helped to observe the tendency of dividing into three groups, and subgroups are possible.

Temperature, light and water are factors influencing the flowering and fruit bearing of *Jatropha curcas* L. We observed that every change of phenology during the growth is connected with effective accumulated temperature. For example, it takes about 20 days from buds to full blossom in early spring, while only about 10 days in summer. The impact of light on flowering and sex ratio is the most obvious. With enough light and no shade, many branches are flowering and female flowers are at a higher rate. On the contrary, the plants under heavy shade are flowering less and female flowers are at a lower rate. *Jatropha curcas* L. grows well in damp soil; however, water logging may lead to plant growth stagnancy, even death. Pest control is very important in *Jatropha curcas* L. plantation. According to recent survey, over 20 diseases and pests are found in *Jatropha curcas* L., among which termite, bacterial canker disease and black root disease, etc. are found to be harmful. These factors should be taken into account in *Jatropha curcas* L. plantation.

In addition, we have carried out studies on the screening and breeding of elite species. By using mutant, we have bred a new cultivar - black winkle - leafed *Jatropha curcas* L. We also found groups of high flowers and high oil content in domestic *Jatropha curcas* L. However, related regional experiment and stress resistance are to be carried out.

Summing up the collection of and evaluation on *Jatropha curcas* L. of different geographical provenances is aimed at meeting the demand of biodiesel industrialization in China, provi-

ding data for new germplasm resources collection and breeding elite species, and providing technical support for the large - scale plantation of *Jatropha curcas* L.

Keywords: *Jatropha curcas* L. ; biological characters; agronomical characters; physio - ecological properties; new varieties.

目　　录

第一章　膏桐研究综述

第一节　膏桐的分类地位及植物学特征

一、分类地位

膏桐（*Jatropha* L.），这个属隶属于大戟科（Euphorbiaceae）、巴豆亚科（Crotonoideae）、Jonnesieae 族，已知物种约 170 个。Dehgan and Webster（1979）订正了 Pax（1910）命名的亚科和现在研究的膏桐属两个亚属，包括旧世界物种 10 族和新世界物种 10 个，把膏桐设定为膏桐属中最原始的类型。其他族内物种都是从膏桐或其他祖先演化而来的，因为它们的生长习性和花的构造发生了变化。膏桐属新世界 77 个物种的 Herarchical 聚类分析表明它们的绝大多数器官和 Dehgan and Webster's 描述是一致的（Dehgan and Schutzman，1994）。

Mc Vaugh（1945）认为 *Jatropha. yucatanensis* Briq. 是膏桐的同物异名，*J. villosa* Wight 一种起源于印度，*J. afrocurcas* Pax. 和 *J. macrophylla* Pax. & Hofm. 两种起源于东非（非洲东部），族内其余的都是美洲原住物种。

大戟科（Euphorbiaceae）大约有 321 属 8000 种植物组成。根据 Leon（1987）、Mabberley（1987）和 Rehm and Espig（1991）等人的研究，此科植物中经济价值比较大的有以下几类：

根（roots）：木薯（cassava：*Manihot esculenta*）

橡胶（rubber）：橡胶（Hevea：*Hevea brasilliensis*）

果实（fruits）：emblic，Otaheit gooseberry（*Phyllanthus emblic*），tjoopa，rambai，mafai（*Baccaurea* spp.），Chinese laurel（*Antidesma bunius*），*Ricinodendron* spp.

坚果（nuts）：tacay（*Caryodendron orinocense*）

蔬菜（vegetables）：katuk（*Sauropus androgynus*），chaya（*Cnidoscolus chayamansa*）

油料（oil）：蓖麻 castor（*Ricinus communis*），桐油树 tung trees（*Aleurites* spp.），肥皂果 Chinese tallow tree（*Sapium sebiferum*），膏桐 physic nut（*Jatropha curcas*）

碳氢化合物（hydrocarbon）：大戟属植物 *Euphorbia* spp.

药用植物：*Croton* spp.，*Jatropha* spp.

在膏桐属内，尽管大多数为新世界原住物种，但其中 66 种仍属于旧世界原住物种。Dehgan and Webster's（1979）提供的检索表不应该认为是最后的，因为仍有许多物种分类依据匮乏，旧世界没有订正的物种依然存在。Hemming 和 Radcliffe - Smith（1987）订正的索马里 25 个物种，全都是膏桐亚属的，它们分别放在 6 个族和 5 个亚族内。其

中 Peltatae 族的 *Jatropha multifila* L. 和 *J. podagrica* Hook.，Polymorphae 族的 *J. integerrima*，Jatropha 族的 *J. gossypiifolia*（腺毛膏桐）都是热带地区著名绿化美化植物。

Linnaeus（1753）首次按照"物种起源"双名法把药用坚果命名为膏桐（*Jatropha curcas* L.），并一直沿用至今。根据 Dehgan and Webster's（1979）和 Schultze – Motel（1986）的研究，药用坚果的同物异名有以下几种。

紫腺膏桐 *Curcas purgans* Medik.，Ind. Pl. Hort. Manhem. 1：90. 1771；Baill. Etud. Gen. Euphorb. 314，1858

美洲蓖麻 *Ricinus americanus* Miller，Gard. Dict. Ed. 8. 1768

可食性膏桐 *Jatropha edulis* Cerv. Gaz. Lit. Mex. 3：supl. 4. 1794

线叶膏桐 *J. acerifolia* Salisb.，Prodr. Chapel Allerton 389. 1796

伊拉克蓖麻 *Ricinus jarak* Thunb.，Fl. Javan. 23. 1825

安得索尼膏桐 *Curcas adansoni* Endl.，ex Heynh. Nomencl. 176. 1840

印度膏桐 *Curcas indica* A. Rich. In Sagra，Hist. Fis. Pol. Nat. Cuba 3：208. 1853

雅卡坦膏桐 *Jatropha yucatanensis* Briq. Ann. Cons. Jard. Geneve 4：230. 1900；Standley，Contr. U. S. Nat. Herb. 23：640. 1923；McVaugh，Bull. Torrey Bot. Club 72：35. 1945

膏桐 *Curcas curcas*（L.）Britton & Mill sp.，Bahama Fl. 225. 1920

Jatropha 这个属的名称是从希腊文的 iatrós（doctor）和 trophé（food）演化而来的，意为药用。按照 Correll and Correll（1982）的研究，curcas 是印度马拉巴（Malabar）药用坚果的通用名。在中国该植物曾被译为麻疯树、小桐子、小油桐等。但最早使用的名称，就是膏桐，倒如民国年间（1931）云南林业发展规划中就有"发展油桐和膏桐……"的表述。

药用坚果有很多的地方名称（俗名：Vernacular）：

药用坚果（Physic nut）、通便果（Purging nut）[English]

pourghére，pignon d'Inde [French]

purgeernoot [Dutch]

purgiernuβ，brechnuβ [Germany]

purguiera [Portuguese]

fagiola d'India [Italian]

dand barrî，habel meluk [Arab]

kanananaeranda，parvataranda [Sanskrit]

bagbherenda，jangliarandi，safed arand [Hindi]

kadam [Nepal]

yu – lu – tzu [Chinese]

sabudam [Thailand]

túbing – bakǿd [the Philippines]

jarak budeg [Indonesia]

bagani [Cote d'Ivoire]

kpoti [Togo]
tabanani [Senegal]
mupuluka [Angola]
butuje [Nigeria]
makaen [Tanzania]
piñoncillo [Mexico]
coquille, tempate [Costa Rica]
tartago [Puerto Rico]
mundubi - assu [Brazil]
piñol [Peru]
pinón [Guatemala]
——(Munch 1986; Schultze - Motel 1986)

二、植物学特征

膏桐是一种耐旱植物，作为一种绿篱在热带地区有广泛的栽培。在传统医学里，它的各个部分都具有药用价值。但是，它的种子对于人、畜则是有毒的。20世纪上半叶，佛得角曾有大量的膏桐种子生产，并一度在该国国民经济建设中占有较大比重。种子作为油脂和肥皂的生产原料被出口到里斯本和马赛。然而今天，全球的生产都把膏桐给遗忘了。

膏桐，确切地说，是一种小乔木或大灌木，高可达5~6m。这种植物显示环节状生长，在每个增量终止处都留有一个形态学环节。它的休眠期长短因雨水、温度和光照的波动而变化。其分枝内有乳液。正常情况下，实生幼苗有5条根，1条根在中心，4条根在边缘。而通过营养繁殖（或无性繁殖）形成的植株则没有主根（Kobilke, 1989）。有5到7个浅裂片、长和宽6~15cm的叶，呈互生排列。花序在枝顶端生，较复杂，分为带萼片的主花序和副花序。植物学上，它可能被描述为聚伞状花序或二歧聚伞花序。该植物为雌雄同株，花都是单性的，分为雄花和雌花，偶有两性花发生（Dehgan and Webster, 1979）。在雄蕊群中，有10个雄蕊，分成有两轮，每轮5个雄蕊，紧密地靠在一起，排列在花丝顶端。在雌蕊群中，3个细长的花柱合生，至其长度的2/3处分叉，并膨大为粗壮的柱头。

膏桐为虫媒花，即它的花粉是由昆虫传递的。但Dehgan and Webster（1979）却认为膏桐花粉是通过蛾类传递的。因为膏桐在夜晚的芳香和甜味、淡绿的花冠、多面的花药和突出的性器官、丰富的花蜜和缺乏显而易见花蜜导管。当昆虫被从温室中赶出来后，不采用人工授粉，果实内种子就不会发生，偶有两性花能够自花授粉。在田间试验期间，Heller（1992）观察到了大量不同的访问过膏桐花并传粉的昆虫。在塞内加尔，他观察到在同一个花序上雄花比雌花开得晚。在一定程度上，这种机制促进了交叉授粉。Münch（1986）在佛得角并没有观察到这种物候节律，说明这种机制受环境的影响很大。授粉之后，一个具三室的椭圆球状的果实即开始形成。在种子成熟以前，外果皮一直保持新鲜状态。膏桐种子是黑色的，长2cm，宽1cm，种阜（caruncle）颇小。Wiehr（1930）和Droit（1932）详尽地描述了膏桐种子的宏观解剖构造，而Singh