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Research Development and Utilization Status on *Jatropha curcas* in China

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1. General situation of *J. curcas* resources in China

1.1 Growth habit

J. curcas has a wide range of adaptation, and is able to endure drought and barren; as its root system is well developed, it can grow on the barren wasteland (cobbly soil, coarse soil, and limestone open ground etc.); it is photophilous, and loves warm and thermal climate. Wild *J. curcas* are mainly distributed in dry and hot subtropical zone and humid tropical rain forest. They usually grow on the flat ground, hills and river valley barren mountain slopes, and their height above sea level shall be 700m-1600m. *J. curcas* has certain cold resistance, and is able to endure a short-time low temperature of -5℃. It is not demanding of the soil fertility of its growing place, as long as the pH value is 5-6 and the soil drainage is good. They are usually planted as hedge around the land, and there are also semi-wild *J. curcas*, which often grow among the shrubs beside the flat-ground road, and are scattered (Li et al., 2007; Gou & Hua, 2007).

1.2 Resources distribution

J. curcas in China are mainly distributed in the south subtropical dry and hot river valley areas. They are planted or wild in provinces (areas) of Guangdong, Guangxi, Yunnan, Sichuan, Guizhou, Taiwan, Fujian, and Hainan etc, and are planted in the west, southwest and middle part of Yunnan, as well as in the drainage basins of Yuan River, Jinsha River, and Lancang River (Liu et al., 2008); In Guangxi, they mainly grow in Qinzhou, Bobai, Rong County, Cangwu, Nanning, Yining, Longzhou, Ningming, Baise, Lingyun, and Du'an etc. In, Sichuan Province, they are wild or planted in Panzhihua, Yanbian, Miyi, Ningnan, Dechang, Huili of Xichang, Jinyang, and Yanyuan etc. In Guizhou, they are mainly distributed in the south and southwest part; the south subtropical dry and hot river valley areas at the drainage basins of Nanpan River, Beipan River and Hongshui River are the cultivation centers; and they are sparsely distributed in cities or counties of Luodian, Wangmo, Ceheng, Zhenfeng, and Xingyi etc. In recent years, the new *J. curcas* forestation area in Zhenfeng, Wangmo, Ceheng, Luodian etc has exceeded 1500hm, and *J. curcas* experimental forest demonstration base and the seedlings base have been preliminarily established in Zhenfeng County, Xingyi City, and Luodian County (Yu et al., 2006; Yang et al., 2006; Yuan et al., 2007).

1.3 Research history

In the past 3O years, the Chinese researches on *J. curcas* mainly focus on the following aspects: the research on *J. curcas* plant resources, the research on the isolation and expression of antifungal proteins and relevant gene of *J. curcas* seed, the research on the separation and purification of curcin and on the gene cloning action mechanism, the rapid propagation of *J. curcas* and the establishing of Medicinal-plant Network Database. After the national "Eighth Five-Year Plan", "Ninth Five-Year Plan" and "Tenth Five-Year Plan", the research and development of biomass energy in China has made considerable achievements. In recent years, as energy shortage in China has become increasingly serious, the development of *J. curcas* has aroused wide concern. In 2004, the Ministry of Science and Technology listed the "biomass fuel oil technological development" into the "Tenth Five-Year Plan" National Key Programs for Tackling Key Problems. The Resource Entomology Research Institute of Chinese Academy of Forestry and the Sichuan University etc have conducted relevant researches for many years, and have yielded substantial results. Xiangtan University and Hunan Academy of Forestry Sciences have also carried out the research on the extractive technique of *J. curcas* oil. In recent years, the development and exploitation of forestry biomass energy have been highly valued by the National Development and Reform Committee and the State Forestry Bureau. In 2006, the State Forestry Bureau established the forestry biomass energy office, adopting *J. curcas* as the preferred tree species for forestry biomass energy development. The local government and scientific research departments made great efforts in the research and development, and not a few enterprises and self-employed entrepreneurs also took part in the planting and development. Nowadays, China has not only set up the Southwest Region Energy-plant Database, screening out 8-9 fine varieties of *J. curcas*, established a 133.3hm seedlings base in Panzhihua and the high-quality and high-yield *J. curcas* planting technology system, but also has established the productive technology and enterprise standard for the new-type motor biodiesel made from *J. curcas*. The extraction of biodiesel from *J. curcas* has gone through experimental stage, and the products have also passed the trial of Chengdu Bus Company, and can absolutely be used for automobile engines. However, the production and exploitation of oil plants in China has just started, and the extraction and processing of some energy crop oil is still in the preliminary test stage (Li et al., 2007).

2. Basic research progress of *J. curcas*

2.1 Biologic characteristics

J. curcas, alternate names are *J. curcas*, fake peanut tree, Qingtongmu, Huangzhong Tree, smelly tung tree, Liangtong, Shuiqi, tung oil tree etc, this plant is a small arbor, 2-5m high, bark is smooth, sap is milk white; leaves are alternate, circular, and have long petiole, clustering tree tops; entire margin or lobed into 3-5 margins, 10-15cm long. Oblong and light green petals, there are nodes on the upper pedicels of staminate flowers, and no node on the upper pedicels of pistillate flowers, the flower is tiny, sepals are quinquepartite; 8-l2 pistils, 2-4 cells in an ovary. Fruit is yellow, spherical, like a loquat; mature seed is black, episperm is gray black, smooth, when the hull is removed, there will be three peanut-like seeds inside, the seed is oblong and 18-20mm long. There are about 200 kinds of J. plants all over the world. And mainly five kinds of J. plants are planted in China, that is: *J.curcas*, *J.podagrica*, *J.multifida*, *J.gossypifolia*, and *J.integerrima* (Liu et al., 2008).

2.2 Reproductive ecology

J. curcas is monoecious and diclinous, cymose. Its inflorescence formation and flowering time is in April, *J. curcas* in China are mostly budding in early March; with the rising of air temperature, the inflorescence grows and develops, and the inflorescence goes through a growth stage of 15-20d. Its bloom stage is mainly from the last ten-day of April to the first ten-day of May, during which period 80% of the flowers will come out (Liu et al., 2010a). The flowers of *J. curcas* mostly aggregate at the stem or the top of lateral branch, and some of them are formed at the leaf axil. The rachis top of indefinite inflorescence does not immediately develop into a flower, and still keeps the ability of germinating and producing a lateral flower. The rachis top of definite inflorescence will soon develop into a terminal flower (pistillate flower, usually grows at the top or leaf axil of the inflorescence), and therefore loses the growing ability. 2-4 lateral rachises will grow under the terminal flower, and the top of lateral rachis will soon develop into a terminal flower (which is also mostly pistillate flower), and 2-4 lateral rachises will grow under this terminal flower; the blossoming order is that the uppermost and innermost flowers mature and come out, while for the downmost and outmost flowers, some of them mature and come out and some fail to mature and therefore dry up and fall off; as a result, the staminate flowers that actually pollinate the terminal flower (pistillate flower) are far less than the staminate flowers that have ever grown (Li et al., 2007; Yang et al., 2007; Liu et al., 2010b). In short, pistillate flowers are mostly terminal flowers, and staminate flowers are distributed around the terminal flower. In the inflorescences that grow on top of the branch, except for the terminal flowers on the definite rachis and a few terminal flowers on the lateral rachis, there are all staminate flowers; in the inflorescences that grow nearer the top, there are appreciably fewer and fewer pistillate flowers, and some inflorescences solely have staminate flowers, without any pistillate flower (Luo et al., 2008). In one and the same inflorescence, there are far more staminate flowers than pistillate flowers. The ratio of pistillate flowers to staminate flowers is approximately 1: 10. Therefore, pistillate flowers have a high probability of being pollinated, and the rate of fruit setting is 100% (Guo et al., 2007).

2.3 Seed biology

The seed of *J. curcas* contains various ingredients, mainly including fatty substance, protein and polypeptide, terpenoids and some micromolecule substance, yet the substance contents vary according to different producing places (Table 1 & 2). The fatty substance of the *J. curcas* is mainly distributed in the kernel, and contains many chemical constituents such as alcohol, acid, ketone, and anthracene (Deng et al., 2005). Its fat content is high, and oil content is 40%-60%, exceeding the common oil crops such as rapes and soybeans, and its oil is of good fluidity. The seed oil of *J. curcas* can blend well with diesel, gasoline, and ethyl alcohol, and after blending, there is no separation for a long period of time; by chemical or biological conversion, the biodiesel that is superior to the existing 0# diesel can be obtained. The protein content of *J. curcas* seed is l8.2%, and its main constituent is curcin, whose toxicity is similar to the ricin of the seed of Ricinus communis and the crotin of the seed of Croton tiglium (Lin et al., 2004). Curcin is capable of inhibiting the gastric carcinoma cells, mouse myeloma cells and human hepatoma from proliferation in vitro. At present, the full-length cDNA sequence and gene sequence of curcin has been cloned, and have expressed the active curcin mature protein and the conserved domain protein in the escherichia coli (Lin et al., 2003; Chen et al., 2003).

Compounds	*Retention time (min.)*	*Percentage (%)*
2-propyldecan-1-ol	11.73	0.95
2-octyldodecan-1-ol	12.53	0.59
1,2-benzenedicarboxylic acid	14.61	16.65
Hexadecanoic acid	15.16	18.02
2-hydroxy-cyclopentadecanone	15.23	1.88
9-hexadecenoic acid	16.02	1.48
9-octadecenoic acid	16.3	44.04
9,12-octadecadienoic acid[Z, Z]	16.94	0.52
Znthracene 9,10-dimethyl	17.47	0.46

(Cited from Li et al., 2000)

Table 1. Chemical composition and its content within mixed seed samples of *J. curcas*

Fatty acid compostion	*Cities or Counties*					
	panzhihua	binchuan	ningnan	yongsheng	shuangbai	luodian
Myristic Acid (C14:0)	0.09	0.04	0.07	0.06	0.05	0.11
Palmitic Acid (C16:0)	17.25	16.84	16.64	13.47	14.88	16.41
palmitoleic acid (C16:1)	1.08	0.53	0.9	0.74	0.87	1.13
Seventeen carbonic acid (C17:0)	0.13	0.08	0.14	0.11	0.13	0.12
Seventeen nonadecenoic acid(C17:1)	0.06	0.03	0.06	0.07	0.05	0.07
Stearic acid (C18:0)	7.42	7.83	7.96	6.43	9.81	5.58
Oleic Acid (C18:1)	40.31	42.44	44.91	40.26	46.03	37.91
Linoleic Acid (C18:2)	32.69	32.67	28.02	38.04	27.78	37.02
Linolenic acid (C18:3)	0.4	0.21	1.06	0.38	0.4	0.64
Arachidic Acid (C20:0)	0.22	0.11	0.25	0.25	—	0.66
Twentieth nonadecenoic acid(C20:1)	0.23	—	—	0.1	—	0.15
Behenic acid (C20:2)	0.13	—	—	0.1	—	0.18
Total	100	100	100	100	100	100
Saturated fatty acid	25.11	24.54	25.06	20.32	24.87	22.88
Unsaturated Fatty Acid	74.89	75.46	79.94	79.68	75.13	77.12

"—" indicates Not test
(Cited from Li et al., 2006)

Table 2. Fatty acid composition of *J. curcas* seeds in different areas (%)

2.4 Good-seed breeding basis

As *J. curcas* is equally fit for seedling propagation and asexual reproduction, therefore, "sexual propagation, asexual utilization" is also applicable to the good-seed breeding of such tree species. However, in the process of new-variety breeding, clonal breeding shall be adopted to meet the requirements for a new variety and to ensure the consistency and stability. In a manner of speaking, the new-variety breeding for *J. curcas* oil-plant energy forest is to breed the clonal varieties that are full-seed and high-quality, and have high and stable yields. As is mentioned above, some of the genesiological characteristics of *J. curcas* need to be further researched to enable the experiments such as mating seed production and hybrid seed production go smoothly. At present, the good-seed breeding research of *J. curcas* adopts "a combination of sexual and asexual"; the selected good individual plants of *J. curcas* are priorly used for building the cutting orchard, and the clonal test plantation is built by cuttage propagation, so as to select the good new varieties for production application; furthermore, provenance/family determination is carried out to select the good provenance or family, and the good family within the good provenance will go through further asexual reproduction; and then clonal breeding is carried out to appraise and select the good new varieties for building the oil-plant energy forest an enlarged scale and for cultivation and utilization.

Fig. 1. The good-seed breeding experiments of *J.curcas*

2.5 Cultivation physiological ecology

The planting and reproduction modes of *J. curcas* usually are direct seeding forestation, seedling transplanting, hardwood cutting method, hedge planting method and tissue culture method etc. The direct seeding forestation is fit for rainy season, the rate of emergence for large-area seeding is usually 50%-70%, and the emergence time varies, generally 10-40d; this method is easy and convenient. Seedling transplanting can cultivate strong seedlings, beneficial to resisting plant diseases and insect pests and improving survival rate. Hedge planting method is a preferable planting method for planting beside the fertile agricultural arable land. Hardwood cutting method is a simple and convenient planting method of *J. curcas*, as long as the tree pond is of certain depth, which is usually around 30cm, and reasonable time is chosen, normally it can survive. In the conducted cuttage experiments of *J. curcas*, the cuttings' survival rate is above 80% (Li & Liu, 2006). The tissue culture technique of *J. curcas* is approaching to maturity, and usually the explants such as embryonal axis, petiole and cotyledon are used for induction. *J. curcas* can be used for dibble-seeding afforestation, its budding ability is good, and it is also fit for cuttage propagation. Those through seminal propagation can germinate the typical taproot and 4 lateral roots, while those through cuttage propagation can not germinate the taproot. Normally, a plant of about 3m can be grown into in 3 years. Those through seminal propagation can bear fruits in 3-4 years, and those through cuttage propagation can bear fruits in 1 year or so (Li et al., 2007).

3. Research on the cultivation techniques of *J. curcas*

3.1 Division of ideal habitats for *J. curcas*

China is extremely abundant in *J. curcas* resources. The distribution of *J. curcas* resources across the country and their ecological habits in different provenances have been generally found out after investigation The adaptability evaluation and the division of ideal habitats for *J. curcas* have been carried out, and meanwhile, introduction breeding is practiced and the *J. curcas* seedlings breeding base is established.

In Yunnan Province and Sichuan Province, according to the analysis of *J. curcas*'s demand for ecoclimate conditions, the *J. curcas*'s ideal and less ideal habitats in the provinces are proposed, and meanwhile the ideal habitats for *J. curcas* are determined after considering the conditions of forest site, such as Lijiang City, Chuxiong City and Panzhihua City. For provinces such as Zhejiang and Fujian where there is no resources distribution, the growth performance of different provenances is compared, to determine the suitability of planting the *J. curcas* there, or to screen out the provenances and varieties that suit the local ecological conditions.

3.2 Good-seedling breeding for *J. curcas*

In order to meet the large-scale forestation's requirements for good seedlings, the researches on seed development, budding characteristics, pre-sowing treatment etc become particularly important, and seedlings breeding research has become the hot topic in cultivation research. According to research findings, *J. curcas* seed reaches its physiological maturity 58d after flowering; the seeds in different geographical provenances have no much difference in apparent characters, while their thousand seed weight is of marked difference, therefore the thousand seed weight can act as the selection index for good material. The optimum temperature for seed germination of *J. curcas* is 25-35°C; seed coat and seeding depth have something to do with seed germination, while sunlight makes no difference to germination; the seed of *J. curcas* belongs to the orthodox seed of light neutrality. Research on the pre-sowing treatment of *J. curcas* has shown that dressing the seeds with 98% concentrated sulfuric acid for 30min is the best treatment, and after seeding, the treated seeds can sprout

1-2d earlier than the control group. Hardwood cutting is the main method for *J. curcas* afforestation, and the cutting seedlings have the characteristics of branching quickly, growing fast, and bearing fruits early; the one-year or two-year branches that are 25cm long are preferable; ABT1 rhizogenic powder and KMnO4 can both enhance the *J. curcas* cuttings to take root, and temperature, sunlight, and soil etc also affect the root-taking of cutting branches.

3.3 Afforestation technique

According to the ecological habits of *J. curcas*, the reproducing area shall preferably have a mean annual temperature of 18-28.5°C, a extreme minimum temperature of -4°C, long frost-free season, long duration of sunshine, and a high yearly accumulative temperature (Yu & Ding, 2009). Preparation of soil shall adopt zonal clearing or blocky soil preparation; density of plantation is normally 840-1110 plant/hm, while for areas with high management level, the afforestation can go by 1665 plant/hm. When transplanting the nursery stocks, decomposed farmyard manure shall be applied to the bottom of the holes, and after revival from transplanting, the lack shall be timely supplied and fertilizer for seed bed shall be additionally applied. As the *J. curcas* forest land is in good ecological environment and hydrothermal conditions, weeds multiply fast, therefore timely nurturance is necessary so as to increase the survival rate and preservation rate of afforestation, and enhance the afforestation effect.

Fig. 2. Artificial forest of *J. curcas* in dry-hot valley of JinSha River

3.4 Main plant diseases and insect pests

The main plant diseases of *J. curcas* are 11 types: *J. curcas* leaves brown spot, cuttings blight, cuttings canker, damping off, powdery mildew, sootymould, anthracnose, seed mildew and rot, rot, gray mold, and leaf spot. And the insect pests are Maladera sp, wireworm, Tetrangchus urticae Koch, Aphis nerii Boyer de Fonscolombe, Nipaecoccus vastator Maskell, aphid, Poecilocoris rufigenis Dallas, white ant, cutworm, leaf miner, and inchworm. Termite, cold damage, rats, and crickets can also endanger the *J. curcas*, and prevention and control measures have been formulated according to local situations.

Fig. 3. The main diseases within *J. curcas* grown in dry-hot valley of Red River

4. Existing problems and development tendency

4.1 Problems and suggestions

At present, there are a lot of problems existing in the development and exploitation of *J. curcas* in China: (1) Raw material resources of *J. curcas* are deficient. For a long time, the importance attached to the research and development of energy plants is far from enough, therefore, insufficient resources have been cultivated, biodiesel raw-material forest falls short, and productivity is low. The bottleneck problem of development is the source of feed, thus can not stand comparison with petroleum diesel. (2) The intrinsic drawback of *J. curcas* oil, which restricts the extent of its application. *J. curcas* oil molecule is big, and viscosity is high, prone to cause incomplete combustion. (3) Improvement of productive technology and degradation of higher aliphatic acid, the cultivation techniques and biotechnology of raw materials, oil processing technology system assembly and cost reduction etc. At present, biodiesel is prepared through the agency of ester exchange reaction catalyzed by homogeneous base catalyst such as sodium (potassium) hydroxide or sodium methoxide, which will make the reaction mixture saponified into the colloidal state, making it hard to separate; during after-treatment, it is likely to lead to wastage of catalyst and discharge of wastewater. (4) A lot of issues related to commercial application of *J. curcas* fuel oil have yet to be solved, such as the preferential policies of tax abatement or tax exemption (Liu et al., 2006).

4.2 Development tendency and prospects

J. curcas has great potential for market development, further research and exploitation will bring considerable economic benefit to mankind, and its exploitation prospect is broad. As the raw material for production of biodiesel, *J. curcas* is being exploited as one of the important energy plants, and is the tree species most likely to substitute for fossil energy in the future, having immense exploitation potential. The arboreal and shrubby oil plants that are the raw materials for biomass fuel oil can be planted in the inferior land in China, including the extensive mountainous areas, sand areas, and arid valley areas, to develop the biomass fuel. Planting biomass fuel plants in these areas not only can provide abundant regenerative raw materials for the biomass fuel oil industry of China, but also will help improve ecological environment, increase farmers' income, and provide a new approach to building a well-to-do society in villages.

The seed of *J. curcas* contains many active constituents, has important farm chemical and medical value, and is a bioenergy plant material with high comprehensive values. As to the research results of molecular biology in recent years, DNA and RNA extraction method has been established, and several kinds of functional genes have been successfully cloned. Furthermore, the plant regeneration and transgenic system has been established, therefore, *J. curcas* has s great prospect as the model plant for energy plant research. However, *J. curcas* is notoriously terrifying because of its high toxicity. Many researchers only researched into poison prevention or making toxicants out of its toxicity etc, while few have considered making use of its medicinal value. And it is believed by some scholars that the possibility of deriving the medicine-origin lead compound from poisonous plants is high. There have been reports on successfully developing new drugs out of poisonous plants, and aroused the close attention from extensive medical workers; therefore, phytotoxin as the medicine origin of lead compound has a promising application prospect (Gou & Hua, 2007). *J. curcas* contains many toxic ingredients, especially the curcin contained in its seeds, an in-depth research of which is expected to bring good economic benefit.

5. Acknowledgements

This paper funded by National Science and Technology Support Program(2011BAD38B04; 2007BAD50B04) .We thank the resident of Yang Jun-Hua, our colleagues of Luo Chang-Wei, Cui Yong-Zhong and Zhang Chun-Hua, and graduate students of Wang Xiao-Qin and Peng Hui for their participation and friendship.

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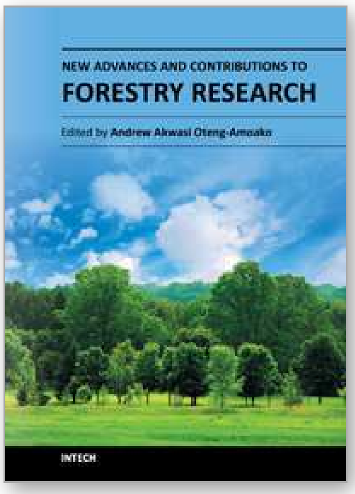

New Advances and Contributions to Forestry Research

Edited by Dr. Dr. Andrew A. Oteng-Amoako

ISBN 978-953-51-0529-9
Hard cover, 256 pages
Publisher InTech
Published online 27, April, 2012
Published in print edition April, 2012

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