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RESEARCH ARTICLE

Distribution and development strategy for *Jatropha curcas* L. in Yunnan Province, Southwest China

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Abstract Yunnan Province is the main distributing area of *Jatropha curcas* L. This plant is abundant in several drainage areas of the dry-hot, dry-warm and sub-humid valleys in the south subtropical area of Yunnan Province. The seeds that were picked from trees blossoming between April and May and fructifying between September and October will have large seed yield and fine quality. For developing bio-diesel stock forest of *J. curcas* in areas with adaptive climate, seeding measures for afforestation should be taken and techniques on breeding, fast-growing, and high-yielding plantation cultivation are very important.

Key words Yunnan Province, *Jatropha curcas* L., geographical distribution, resource status

1 Introduction

Jatropha curcas L. is a kind of shrub species of the *Jatropha* genus, Euphorbiaceae family, and is also called Gaotong, Choutong, Huangzhongshu and Jiahuasheng in Yunnan, Sichuan, Guangdong, and Guangxi, respectively. It defoliates in the dry season. It is also called physic nut in some places. Though it is a native species in tropical areas in America, it is widely planted in tropical and subtropical areas around the world. In China, it is mainly distributed in Yunnan, Sichuan, Guizhou, Guangxi, Guangdong, and Hainan (ECFCNASC, 1996; Zhang et al., 2001).

J. curcas has numerous uses. It is planted as a medicinal plant domestically and abroad due to its bark, leaves, and seeds that have many medical uses, e.g., the press cake for oil expulsion. The seed oil is semi-dry and light yellow, specific gravity (20°C) 0.914, index of refraction (20°C) 1.463, acid number 16.82, iodine number 93.79, saponification value 192.2, and fatty acid consisting 47.5% oleic acid and 30.3% linoleic acid (Zhong, 1984, 1986; Shi et al., 1992; Zhang et al., 1992). The seed oil yield is high and its cetane value is greater than that of the European standard (Table 1). The combustion property of the seed oil is near that of the ordinary diesel fuel and can be directly used as liquid fuel in diesel and industrial boiler. Therefore, *J. curcas* attracts global attention (Zhong, 1986; Li, 2000). At present, the plant has been cultivated on a large scale in India and developing countries in Africa to substitute for timber and fossil fuel as domestic and dynamic energy. FAO takes the physic nut seed oil and plant extraction as a pioneering program, and develops it to enhance the ecology construction and reduce poverty in rural areas in Savanna, Africa. Physic nut trees are also planted on a large scale in Uganda, Mozambique and Zambia, and are tested in the development of bio-diesel oil and biomedicine to increase people's income and improve their environment (WRI，1990).

Physic nut is mainly distributed in dry-hot valleys in southwest China, especially in Yunnan Province, the biggest planting area and germ resource. Wide-ranging cultivation has great significance in developing biological energy resources, biomedicine and bio-pesticide industry in China. The plant grows well in dry-hot valleys, so it promotes the recovery of vegetation in the area and has positive effects on the security of middle and lower reaches of the Yangtse River.

2 Materials and methods

2.1 Investigation on growing environment and geographical distribution of *J. curcas*

Based on geography and the distribution of the drainage system in Yunnan, the line transect sampling method on *J. curcas* were used along valleys in Jinsha

Table 1 Comparison between fossil fuel and physic nut oil

Quality	Relative density (30°C)	Viscidity (30°C, $mm^2 \cdot s^{-1}$)	Cetane number	Iodine number (g $I_2 \cdot 100\ g^{-1}$)	Acid number (mg $KOH \cdot g^{-1}$)
Fossil fuel	0.840	3.12	46.00	84.00	0.02
Physic nut	0.885	6.29	44.81	144.00	0.90

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River, Lancang River, Red River, Nu River, Nanpan River, Ruilijiang River, Daying River and etc. If the *J. curcas* planted area is over 3 mu (1 mu=666 m^2), sampling plot (20 m×20 m) investigations are also taken. The investigation indices are tree height, basal diameter, branch number, fruit bunch number, fruit number per fruit bunch, fresh fruit weight and dry fruit weight.

2.2 Growth variation of *J. curcas* in different regions

The following indices of *J. curcas* in different regions are investigated and give a comparison between them, including the flowering biology, fruit setting biology, specific gravity, shelling percentage, oil content. Oil content in seed is measured with ether extraction and calculated as follows.

$$\text{Oil content} = \frac{(m_1 - m_0)}{m_2} \times 100$$

where m_1 is the weight of oil and bottle, m_0 is the weight of empty bottle and m_2 is the weight of dry seed.

2.3 Propagation and cultivation methods of *J. curcas*

Test on seed storage and germination was conducted at Kunming, while seedling culture and afforestation was conducted at the center seedling nursery of the Pu'er Forestry Bureau in south Yunnan. The latter is located at 23°02′N and 101°03′E, with elevation 1,320 m, has an average temperature of 18.2°C and an annual rainfall of 1,393 mm; the annual accumulated temperature reaches (≥10°C) 6,630°C.

3 Results

3.1 Physical geography of Yunnan Province

Yunnan Province (21°09′–29°15′N, 97°39′–106°39′E) is situated in southwest China and has an area of 394,000 km^2. The Yunnan physiognomy is deeply influenced by geological structure. According to plate tectonics, Yunnan is part of the southwest Yangtze plate (middle Yunnan and northeast Yunnan) and the Yunnan-Qinghai-Tibet plate (west Yunnan and southwest Yunnan) of the Eurasian Plate. Due to the late orogenic movement of the Himalayas between the Pliocene Epoch and early Pleistocene Epoch, Yunnan was uplifted strikingly, laying ground for the current Yunnan plateau topography. Yunnan topography takes on a trend that the southeast is generally lower than the northwest because the large-scale tectonic uplift is not equal in height. Moreover, the fractured zones are deep and wide with the northwestward and south-northward zones being the greatest followed by the northeast ward zones. These zones deeply affect topographical development and control the geological structure of Yunnan. Ancient plantation surface fell intensively for hydrographic incision, stream erosion and other outer operative power. On both sides of deep-cut valleys are levels of relatively flat valley shoulders (river terrace), all of which contribute to the present complex physiognomy.

Yunnan topography is famous for its variety and complexity, which greatly affects its climate, agricultural conditions and natural resources. With an average altitude of 2,000 m, the undulating terrain is greatly disparate in height. For the northwest-southeast slanting range, the elevation decreased by 6 m every kilometer from the northwest to the southeast. The highest point is the Meili snow mountain in the Deqin County in northwest Yunnan, whose Kagebo peak is 6,740 m above sea level while the lowest point is about 76 m where the Nanxi River meets the Yuanjiang River in Hekou County in southeast Yunnan. The valley of the Lancang River, whose surface is approximately 2,200 m, is in the east of the Meili Mountain. Less than 50 km from Hekou County are mountains as high as 2,400–3,000 km. The slanting terrain can be mainly divided into six layers. The first layer located at 28°N is occupied by the upper part of the Hengduan mountains in northwest Yunnan whose peak is 5,000 m, ranging from north to south; the second layer is dominated by the ancient plantation surface of the Hengduan mountains which over 4,000 m with montane grassland and pasture belts, between 27°N and 28°N; the third layer is another ancient plantation surface with a height of 3,000–3,200 m between 26°N and 27°N; the fourth layer, situated between 25°N and 26°N and the northern part of 26°N northeast Yunnan is taken by the intact rolling-hill-like 2,000–2,500 m-high plateau and sinked basins distributed in middle Yunnan and has a maximum elevation of 1,700 m; the northern part of the tropic of cancer and its neighboring areas form the fifth layer which holds a flat mesa that is as high as 1,700–2,000 m in south Yunnan and features a rolling-hill-like plateau in the valleys and in-mountain basins with an average height of 1,300–1,500 m; the sixth layer is the southern part of Yunnan and southwest frontier south of 23°N where most are plateau surfaces composed of lower plantation surface about 1,200–1,400 m high, and in which basins in the valleys are with a height of 500–800 m and are well washed. Yunnan plateau is geographically multi-leveled which is made up of sky-high mountains and plateau surfaces of two kinds: rolling-hill-like plateau surface and incision plateau surface. Regions below the plateau surface can be subdivided into mountain surface and valley shoulder, denudation

surface formed with denudation mesa around the basins and stream course basins, which in turn are constituted by plateau river valleys, high-elevation basins, deep-cut river valleys and low-elevation basins.

The slanting topography from the higher northwest region to the lower southeast region resulted in the differences in the height and climate of the different places on the same layer. The Yunnan climate is influenced by geography, the characteristics of the atmospheric circulation and plateau topography. In October each year, westerlies move southward and the Yunnan plateau is dominated by dry and warm tropical continental air mass-south branch of westerly jet flow. In May, westerlies go northward and the south branch of westerlies disappears and the southeast and southwest monsoon rapidly advances towards Yunnan plateau, which results in the entry of the rainy season in Yunnan. Yunnan lies in southwest China, so the southeast monsoon mainly affects the west and the northwest parts. Vast areas of the Yunnan plateau are dominated by powerful southwest monsoon. Meanwhile, in addition to the altitude and latitude factors, the annual average temperature in the southernmost part is 14°C higher than that in the northernmost, though the difference is only five latitudes. Supposing the Ailao mountain is the boundary mountain, the temperature on its east side is lower than that on its west side. The climate zone on the east side is 300–400 m lower than that on the west side because of the effects of geography, altitude, deep-cut sunken river valleys and leeward rain shadow zone. Though the altitude decreases and the temperature increases along the Jinsha River valley, the Red River valley, the Lancang River valley and the Nu River valley, the amount of rainfall drops. In contrast to the plateau mountains and the basins on both sides of the valleys or regions of the same latitude or south of the area, there is a remarkable difference in heat and rainfall. For instance, the dry Jinsha River (Yuanmou, Yunnan), located at 25°44′N with a height of 1,120 m, has an average temperature 21.8°C and an annual rainfall 613 mm; while in Wuding county, which lies east of the Yuanmou basin at 25°32′N and with a height of 1,710 m, annually logs an average temperature of 15.2°C and rainfall of 1,010 mm.

Climate complexity and diversity in Yunnan resulted in various soil types in hilly areas. And even in an interannual year the soil types may be different. Under the influence of tropical monsoons, brick red soil is extensive in tropical rain forests and monsoon forest regions on the sixth layer terrace. On the fifth layer terrace, crimson soil is the main earth component of the monsoon evergreen broad-leaved forest range. Red soil commonly occurs on the fourth layer and the montane regions with high elevation in the middle, south and north of Yunnan. Dry red soil is distributed in the dry stream courses of the Jinsha River on the fourth layer and in the Red River, Lancang River and Nu River on the fifth layer. Montane brown yellow soil (or yellow soil), montane brown soil, montane dark brown soil, podzol and alm soil can be found only in places on and above the fifth layer and other areas below the fifth layer with higher altitude.

3.2 Growing environment and geographical distribution of *J. curcas* in Yunnan

J. curcas originated in tropical America. It has been introduced to South Africa, Mozambique and Zambia in Africa, to Queensland and North of Australia, and to Orlando, Florida and the Hawaiian Islands in America. At present, Yunnan has the widest distribution area of *J. curcas* in China and it is also where the greatest number of the species can be found. The species is a common plant found in drainage areas of the Jinsha River, the Lancang River, the Red River, the Nu River, the Nanpan River, the Ruilijiang River and the Daying River. It has a height of 100–1,600 m in southern subtropical areas and northern tropical areas. Since *J. curcas* thrives in heat, it has an inclination to grow in tropical areas. It is distributed in a belt-like or scattered way along both sides of the trunk and tributary river valleys of the above-mentioned rivers. *J. curcas* is not sensitive to soil type. It can grow in slightly acidic soil, particularly in brick red soil, crimson soil and dry red soil, which is deep and fertile with favorable aeration. *J. curcas* can be planted along roads or ditches, or in vacant places around houses, valleys or even on river flats that have many gravels. But it grows poorly in hardened or sticky lands. Though *J. curcas* likes heat and can tolerate droughts, it grows unsatisfactorily and yields less in barren areas. On the other hand, it grows well, sprouts or buds quickly, develops a great number of branches and broad crowns and becomes burly when planted along valleys, down slopes or in marginal fields.

J. curcas is widely distributed in river valleys below 1,700 m in tropical and subtropical areas of Yunnan. However, the semi-arid and semi-humid river valleys on the fifth layer terrace and the dry-hot valley of the Jinsha River on the fourth layer terrace are the places where *J. curcas* can grow, blossom and bear fruits normally. In the drainage areas of the Jinsha River, the plant is dispersed in dry stream courses below 1,600 m, and in the upper reaches of the courses and dry warm river valleys on a higher elevation. In the middle and lower reaches of the Red River drainage areas, *J. curcas* can easily be found in dry river valleys below 800 m and dry warm river valleys below 1,700 m. It is also found in the upper reaches of the tributary drainage areas of the Lishe River, the Liuzhi River and the Nanjian River. As for the Lancang River Drainage, the species can be found in semi-humid areas and dry stream courses below 1,200 m and in the upper reaches of dry warm courses. In the Nu River

area, the species is found in semi-humid and dry stream courses below 1,100 m. However, *J. curcas* is rare in the Nanpan River which is the upper reaches of the Zhujiang River. Relatively, the species is easily seen in areas with higher temperature south of Panxi. Generally, *J. curcas* is obviously distributed along a belt of stream courses in Yunnan, which is a feature of the Yunnan plateau. And as far as latitude is concerned, *J. curcas* is found in stream courses with high temperature of 25°N and in the dry-hot and dry-warm valleys of the Jinsha River (Fig. 1).

According to Fig. 1, the *J. curcas* distribution areas are in the river valleys below 1,600 m and in sections of the Jinsha River drainage areas from Zhongjiang, Heqing County to Gele, Dongchuan County. Other distribution areas are river valleys below 1,500 m in the Red River drainage areas from the Nanjian basin and Xiaoliuzhi to Manhao, Mengzi County; river valleys below 1,200 m in sections of the Lancang River drainage areas from Gongguoqiao to Jinghongba; river valleys below 1,100 m in sections of the Nu River trunk (tributary) drainage areas from Lushui to Mengxing, Longling and river valleys below 800 m in sections of the Nanpan River drainage areas south of Panxi. So far, artificial planting of *J. curcas* in Yunnan has just begun and there is now a prolific artificial *J. curcas* forest. In adaptive regions, the plant exists in the form of scattered plants or a small area of pure forests or a living fence. It is heliophilous, so the tree is seldom grown in arbor forests or shrubberies. Though native to tropical America, *J. curcas* has long been introduced to Yunnan where it is widely grown in large quantities, and has become localized and distributed in densely populated areas. On the other hand, the plant is rare in sparsely populated area. In other words, the distribution areas and the quantity of *J. curcas* are subject to the frequency of human activities in suitable areas. *J. curcas* is concentrated in residential and industrial areas, thanks to humans' intentional or unintentional planting and excellent ability of renew the tree. In contrast, in remote hilly areas and barren hills or in lands found along the middle or upper hill slope, *J. curcas* is scarce due to the lack of artificial introduction and spreading.

3.3 Growth variation of *J. curcas* in different regions

Though distributed in a vast area in Yunnan Province,

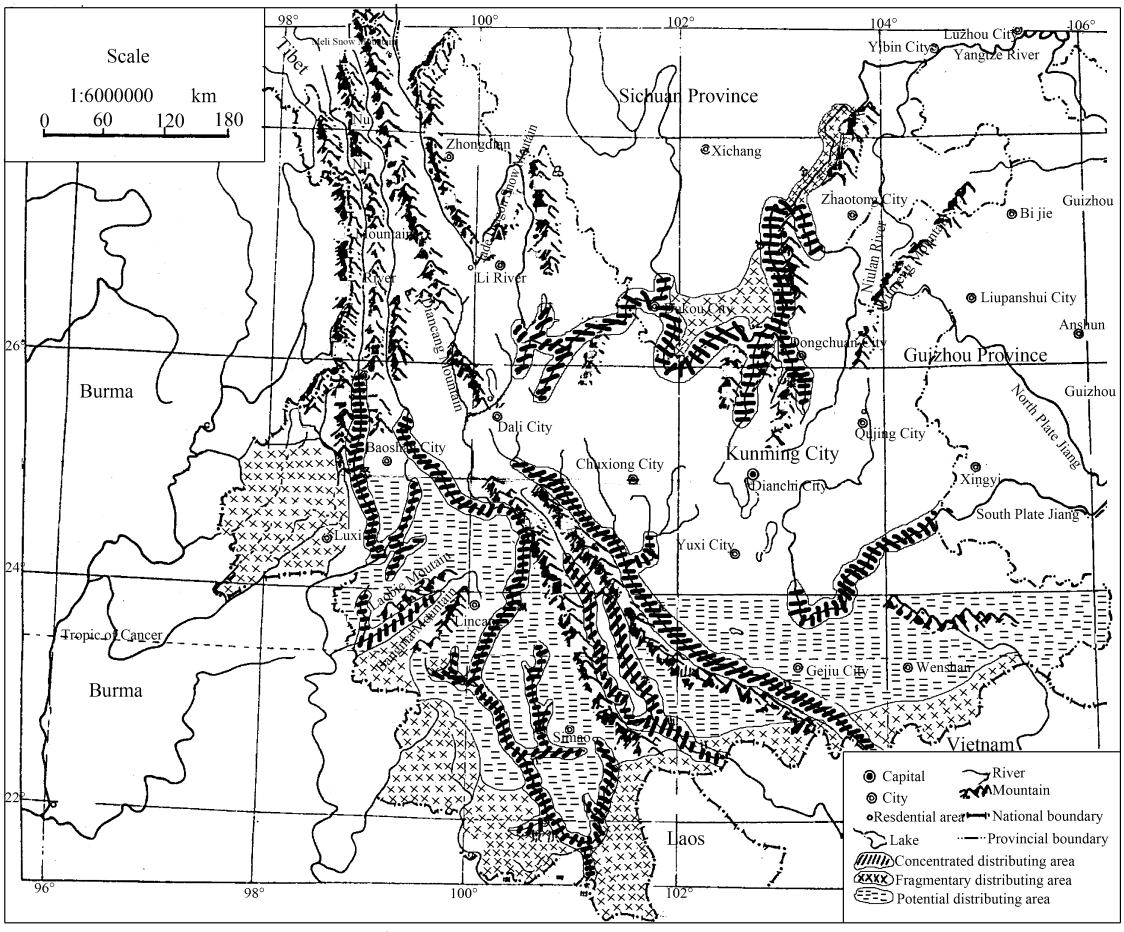

Fig. 1 Sketch map of the distributing and potential distributing area of *Jatropha curcas* in Yunnan Province

J. curcas differs in tree shapes and in blooming and fruiting habits by areas due to the effects of the climate, especially rainfall, topography and the obstruction caused by the mountain ranges. In hot and humid reaches below Manhao in the Red River and Xishuangbanna, and in the lower reaches of the Lancang River, trees grow high, branches are less, tree crowns are narrow and the trees are indeciduate in the dry season, and can blossom and bear fruits synchronously. They can bear fruits twice a year, from March-April and from September-October and yield fruits from August-September and from March-April of the following year. In terms of the amount of blossoms and fruits, the first bearing is better and the seeds are more plump. In dry (dry-warm) river valleys of the Jinsha River, the Red River, the Lancang River and the Nu River, and in the semi-humid and semi-arid areas of the tropical South Asia, the *J. curcas* bears fruits once a year, it blossoms in April and May, yields fruits in September and October, and its leaves fall from December to April of the following year. In the upper part of the Jinsha River valley or in the higher zones such as Yuanmou, the blossoms and fruits drop more frequently and the seeds are not as plump. In some dry-warm areas and in the outspread areas of the dry-hot valleys with high elevation, *J. curcas* will yield less because of the low temperature during the blooming period. In hot and humid tropical zones in the north, during the early rain (humid) season, *J. curcas* is greatly influenced in terms of its blossoming and pollination, which results to the dropping of blossoms and unripe fruits. If there is incessant rain during fruit ripening in September and October, a large number of seeds on the tree or on the ground would decay.

Because of the difference in climate, *J. curcas* seeds' economic properties (seed weight, kernel yield, oil yield of seeds) in different regions vary. In the Jinsha River valley where there is extensive heat, such as in the Yuanmou, Heqing, Yongsheng and in the Yuanjiang basin of the Red River, seed weight is relatively lower, kernel yield and oil yield of seeds are higher because of the shorter time allowed for growth. All three seeds indicators are higher in the upper reaches of the Red River, the Lancang River and the Nu River drainage areas. Along the Liuzhi River, in Shuangbai in the Red River, the Simao valley of the Lancang River, the Nu River from Lujiangba to Lushui and Mang City of the Dehong prefecture, seed weight is equal or greater than 600 g, the kernel yield is above 65% and the oil yield of the seeds generally goes beyond 37.58% (Table 2). The analysis of the correlation coefficient (R) between the above-mentioned economic properties and the temperature in the experimental sites indicates that the accumulated temperature of above 10°C is not closely related to the seed weight (0.379,4) and the kernel weight (0.323,7), but the oil yield of the kernel is closely related to the accumulated temperature. When >10°C annual accumulated temperature is below 7,000°C, the oil yield of the kernel increases as the accumulated temperature increases and the R reaches 0.773,7, whereas when >10°C annual accumulated temperature is over 7,000°C, they are inversely related, the R between annual average temperature and seed weight, and 100-kernel weight, are 0.082,7 and 0.045,1 respectively. Certain annual average temperature is positively related to the oil yield of the kernel. When the annual average temperature is below 21°C, the oil yield of the kernel increases as the temperature becomes higher and the R is 0.665,3; while they are inversely related if the temperature is above 21°C. The reason for this disparity calls for further study. We are doing some experiments to discover whether environmental conditions or genetic properties lead to this effect.

Table 2 Comparison of some economic properties of *J. curcas* seeds in different distribution areas in Yunnan

Index	Yuanjiang dam	Yuanmou basin	Shuangbai of Liuzhi river	Nanjian basin	Yangwu	Bridge of Simao-Lanchang road	Manghuai of Yunxian county	Huangping of Heqing county	Taoyuan of Yongsheng county	Lujiang river dam	Liuku of Lujiang river	Mangshi dam
Seed weight (g)	541.4	500.7	637.8	589.1	597.6	675.7	562.3	450.8	513.4	552.5	698.9	604.3
Kernel weight (g)	325.7	313.3	421.7	378.1	381.3	442.5	331.3	256.8	319.4	342.1	459.7	395.6
Kernel yield (%)	60.2	62.6	66.1	64.18	63.8	65.5	58.9	57.0	62.2	61.92	65. 8	65.5
Oil yield of seed (%)	55.3	53.0	58.51	62.5	61.4	59.3	57.8	62.2	64.25	60.7	59.3	61.2
Oil yield of kernel (%)	33.3	33.2	38.7	40.1	39.2	38.9	34.0	35.5	40.0	37.58	39.0	40.0

Collecting seeds: from 3 to 10 in October, 2005, weigh 500 g seeds randomly, test and sample plump seeds with normal colour (white).

3.4. Propagation and cultivation methods of *J. curcas*

3.4.1 Seeds gather

J. curcas fruits ripen in September and October in most places of Yunnan. During this period, fruits with pericarp change from green to yellow. Those with golden yellow pericarp should be collected. Then, the fruits should be put on hard ground and gently pressed. After the pericarp splits into three parts, jet-black plump seeds should be chosen and packed with cotton bags to air-dry in order to protect the seeds from direct sunlight (Shi, 1992). Dry fruits hanging on the tree for a long time contain unplump seeds, which lose germinating ability after exposure to the sun; seeds that have into the weeds and wet soil tend to decay if not immediately collected.

3.4.2 Seedling cultivation

1) Seedling cultivation: because the *J. curcas* seeds have high oil content, they easily go bad and lose sprouting ability. In Yunnan, seeds that were collected last September and October and were stored in a 5°C container after complete air-drying, will still have over 80% sprouting ability if they are sowed and cultivated in March of this year, and only 40%–50% of the seeds will sprout if they are sowed after May or July. None of the seeds could germinate after March of the following year. Therefore, seeds are not suitable for storage every other year. Seedlings are cultivated in high beds and were drilled with the width of 20 cm and seed width of 5 cm and covered in 1–2 cm of soil. The bed should be kept damp before euphylla burgeons. After four months, the average height of the seedlings is more than 40 cm. Since the seedlings are strong and their root systems are flourishing, and there is no suitable container so far, using containers is not necessary.

2) Cuttings technique: in late February and March of every year, one-year old branches are chosen to make 30-cm-long cuttings. High bed and ridges are formed in soil with good aeration, which is irrigated thoroughly before transplanting. The drilling width is 30 cm and the seedling width is 10 cm. After transplanting, soil moisture of the bed should be kept appropriate and over-watering should be avoided.

3.4.3 Afforestation with seedlings

In areas suitable for *J. curcas*, such as down hillslopes, ditches, river flats and alluvial lands which have deep fertile soil and fine aeration and irrigation conditions, afforestation with *J. curcas* seedlings is recommended. Usually, the soil is prepared in late autumn or early winter by digging ditches or pieces of platforms. The standard dimension for ditches is 50 cm×50 cm, while for platforms its 50 cm×50 cm×50 cm. In May of the following year, fertilizer is used. Afforestation begins in early rainy season (in June and July). 5 kg organic fertilizer; 100 g carbamide and 100 g phosphate fertilizer are applied to each seedling as base manure. The crop density is 2,500 plants/ha. The seedling width and line width is 2 m×2 m. *J. curcas* can be directly sowed only during the rainy (humid) season. The tree grows seldom in such a short period during the first year, so death rate is high during the dry season. The growing period of seedling and afforestation can be as long as 10 months. In areas with good irrigation, cuttings can be transplanted into the field in February and March. Great attention should be paid to irrigation in the dry season after planting.

4 Countermeasure and suggestion to *J. curcas* industrialization development

1) *J. curcas* is widely distributed in river valleys of main rivers and tributary drainage areas in Yunnan. Because the places have differences in climate and soil type, plant growth and the economic properties of the seeds in different sections of the same river are diverse. Differences between individual trees are even distinct. In excellent seeds and seedlings, whose one-plant-seed weight (after air-drying) should reach 1.0 kg, the seed weight is >700 g, the rate of kernel is >70%, and the rate of seed oil is >30%. These make the development of *J. curcas* bio-fuel source forest ideal. Currently, seed types and seedlings should be selected as soon as possible, then cultivated and promoted. Research on genetic breeding should be enhanced and high-quality and high-yield breeds adaptable to all kinds of areas and environments are expected to be developed to support forest construction.

2) At present, *J. curcas* in Yunnan is scattered along paths and ditches and are cultivated as living fences or odd-looking single plants in residential areas. Hilly areas take up 94% of Yunnan, leaving few fine lands for developing bio-fuel source forest of *J. curcas*. To ultimately solve the supply of raw materials, fine breeds should be applied and techniques of afforestation should be developed. Deep fertile soil with fine aeration and irrigation are feasible. Systematic research on techniques of high-yield afforestation with *J. curcas*, in montane areas should be strengthened. We should focus on effectively increasing both the output per unit area and the rate of seed oil and the enlargement of the afforestation areas.

3) The bio-fuel source afforestation of *J. curcas* has just started, but it lacks technical achievements and supplementary facilities. But large-scale production has been initiated, and relevant research should center on the production needs by combining key solutions

with integrated techniques. The establishment of a pilot demonstration forest in development areas should allow the coexistence between experimental research and dissemination of information. This way, a strong scientific and technical support can be provided for production, which in turn would allow for the improvement in the construction of bio-fuel source forest of *J. curcas* in China.

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References

Editorial Committee of Flora China Nica of the Academy of Sciences of China. Flora of China. 1996. Beijing: Science Press, 44(2): 148 (in Chinese)

Li W L, Yang H. 2001. Research on a recycling energy plant *J. curcas* seed oil chemical component analysis. Yunnan Univ. J. (Nat. Sci. Ed.), 22(5): 324 (in Chinese)

Shi Z M. 1992. Research on utilization and cultivation of energy plant *J. curcas*. Yunnan Norm. Univ. J., 12(2): 31–38 (in Chinese with an English abstract)

World Resource Research Institute eds. 1989. World Resources Report in 1988–1989 (Wang Z J trans.). Beijing: China Environmental Science Press, 1–23 (in Chinese)

Zhang W D, Jiang Y H. 1992. Extracting petroleum from green plants. Yunnan Norm. Univ. J., 12(2): 20–25 (in Chinese with an English abstract)

Zhang W D, Song H C. 2001. Development of *J. curcas* and ecological protection in Yuanmou County. Yunnan Norm. Univ. J., 21(5): 37–42 (in Chinese with an English abstract)

Zhong Z Q. 1986. Further research on *J. curcas* seed oil as diesel substitute in Thailand. Res. Trop. Bot., 29(30): 105–107 (in Chinese)

Zhong Z Q. 1984. *J. curcas*—a promising energy plant. Res. Trop. Bot., 62–65 (in Chinese)

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