Fruit Varieties Journal 46(1):16-22 1992

Chinese Hickory: An Emerging Nut-Tree Crop

RUAN YONG-LING[1], BRUCE W. WOOD[2], AND JERRY A. PAYNE[2]

Abstract

Chinese hickory (*Carya cathayensis* Sarg.) is a highly prized southeast Asian nut crop. It is the horticulturally most important species of the six *Carya* species indigenous to Asia and ranks second to pecan [*Carya illinoinensis* (Wang.) K. Koch] worldwide in importance as a cultivated nut crop from the *Hickoreae* tribe of *Juglandaceae*. While it is relatively undomesticated, it nevertheless offers potential as a new nut-tree crop. Basic information is presented which pertains to its distribution, utilization, ecology, genetic resources, cultivation, pests and domestication.

Introduction

Carya is the sole genus of the *Hicoreae* tribe of the *Juglandaceae* family and is comprised of about 20 species which are currently indigenous to either southeastern Asia or North America. The genus consists of sections *Carya* ("true hickories"), *Apocarya* ("pecan hickories"), and *Rhamphocarya* (10). Of the 20 taxa which are generally accepted as full species, 14 are indigenous to North America and six are indigenous to Asia (Table 1). Essentially all of these species bear edible fruit. However, only four have received significant horticultural attention (with worldwide interest being *C. illinoinensis* > *C. cathayensis* > *C. ovata* > *Carya lacinosa*).

Ancient *Carya* species were once present throughout much of the Northern Hemisphere. They are currently more abundant in North America than in Asia and, presumably due to glaciation, have become extinct in Europe (11). Of the several *Carya* species eaten by man, only three appear to have undergone significant cultivation. The Chinese hickory (*Carya cathyensis*) and Hunan hickory (*C. hunanensis*) of Asia and pecan (*C. illinoinensis*) of North America appear to have been items of commerce for at least the last two centuries. For example, the marketing of Chinese hickory is described in the 'Annals of Yuhang County' (1) in the 16th century; additionally, it appears to have been intensively cultivated as early as the 10th century (Li, Zhang Ju; personal communication).

Worldwide, pecan is economically the most significant and widely cultivated of the hickory species (12). However, in Asia, of the six indigenous *Carya taxa* (*C. tonkinensis, C. cathayensis, C. hunanensis, C. poilanei, C. sinensis* and *C. kweichowensis*) and one exotic (*C. illinoinensis*), Chinese hickory is the most important cultivated species and is a highly regarded nut-tree crop of southeastern Asia [The People's Republic of China (P.R.C.), Hong Kong, Macau, and Taiwan]. Most of the other endemic Asian *Carya* species have received little, if any, cultivation. Chinese and Hunan hickories are by far the most commonly cultivated. Chinese hickory is much more popular than is Hunan hickory. The horticultural relationship between Hunan hickory and Chinese hickory is roughly analygous to that between the shagbark hickories (shellbark and the northern and southern shagbark hickories) and pecan in North America. The cultivation of Chinese hickory is of substantial horticultural significance to peoples of certain regions of southeastern Asia. Their experience indicates that Chinese hickory has potential for domestication and utility as a cul-

[1]Department of Horticulture, Zhejiang Agricultural University, Hangzhou, Zhejiang, 310029, P.R.C.
[2]Agricultural Research Service, U.S. Department of Agriculture, Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008.

Table 1. Taxa of the *Hicoreae* tribe of *Juglandaceae*.

Species	Common name[y]	Indigenous location
	Apocarya	
C. illinoinensis (Wang.) K. Koch	Pecan	U.S. & Mexico
C. aquatica (Michx.f.) Laud	Water hickory	U.S.
C. palmeri Mann.	Mexican hickory	U.S.
C. myristiformis Nutt.	Nutmeg hickory	U.S.
C. cordiformis (Wang.) K. Koch	Bitternut hickory	U.S.
C. cathayensis Sarg.	Chinese hickory	China
C. kweichowensis Kuang et A. Lu	Guizhou hickory	China
C. hunanesis Cheng et R. Chang	Hunan hickory	China
C. tonkinensis Leconte	Viet-Nam hickory	Viet-Nam, China & India
	Carya	
C. laciniosa (Michx.)	Shellbark hickory	U.S.
C. ovata (Mill.) K. Koch	Shagbark hickory	U.S.
C. carolinae-septentrionalis (Sarg.)	Southern shagbark	U.S.
C. glabra (Mill.) Sweet	Pignut hickory	U.S.
C. ovalis (Wang.) Sarg.	Red hickory	U.S.
C. floridana Sarg.	Scrib hickory	U.S.
C. texana Buckl.	Black hickory	U.S.
C. tomentosa Nutt.	Mockernut hickory	U.S.
C. pallida (Ashe) Engl. & Graebn.	Sand hickory	U.S.
C. poilanei (Chev.) Leroy	Poilane's hickory	Viet-Nam
	Rhamphocarya	
C. sinensis (Dode)	Beaked hickory	Viet-Nam

[z]Many Asian taxonomists recognize Rhamphocarya as a second genus termed Annamocarya of the tribe of Hicoreae. Additionally, the other Asian hickories are commonly recognized by Asians as being in section Sinocarya.
[y]Most of these hickory species are known by several common names; those listed are most widely recognized.

tivated nut-tree crop in other parts of the world. Due to a general dearth of information, or even an awareness of the species existence or potential, this overview is provided to introduce information relevant to the utilization of Chinese hickory as a horticultural crop. The dearth of horticultural literature on Chinese hickory necessitates that much of the information presented by the authors be based on personal observations.

Distribution

Wild: The native range of Chinese hickory [referred to locally as 'Shan Hetao' (hill walnut)] appears to be centered around the Tian Mu mountains (generally at elevations from 400 to 1200 m) in northwest Zhejiang Province and southeast Anhui Province of the P.R.C. This region (29°-31° N Lat.) includes Linan, Chunan, Anjie, Tong Lu and Jiande Counties of Zhejiang Province and Ningguo, She, and Yi Counties of Anhui Province. The native range is not accurately identified, however it appears to encompass several isolated populations along much of the eastern most portion of the Nan Ling mountain range (which extends across southern China along the borders of Hunan, Guizhou, Guangxi and Yunnan Provinces of China and the borders of Yunnan and Viet-Nam). In contrast, the other Asian *Carya* species appear to inhabit the central and western regions of the Nan Ling mountains in Guizhou, Guangxi and Yunnan Provinces.

Cultivated: Orchard-type or grove-type cultivation of Chinese hickory is largely localized in Zhejiang Province.

While scattered orchards exist in other nearby sections of China, there appears to be little cultivation outside the P.R.C. (there is some in Taiwan or the Republic of China). The P.R.C. has over 19,000 hectares of cultivated trees with about 80% of these trees being of bearing age. Average in-shell yield is about 600 kg per hectare, however some orchards can produce as much as 2,400 kg per hectare. Most of this production comes from Linan county (Zhejiang Province) which accounts for about 60% of the country's production. This county also produces nuts with the highest kernel quality.

This Linan region receives from 130 to 160 cm of annual precipitation with most of it occurring as rainfall from April to June. Seasonal air temperatures vary from a summer high of about 42°C to a winter low of about -14° with an annual average of about 16°, resulting in a frost-free period of about 229 days (2). Under the Linan environment, Chinese hickory requires from 1440 to 1920 hours of chilling (below 5°C) to insure good flowering.

Utilization

The kernels of the nuts of Chinese hickory contain about 70% oil (comprised of 80-95% unsaturated fatty acids) and 11% protein. Meats are sweet tasting when properly processed. The naturally astringent kernel is made palatable by steaming; and as a result, producing a prized dessert item (raw or mixed with sugar and/or spice) and health food. Nuts are also cooked with meats and vegetables. An oil derived from the kernel is used in cooking, sauces and as a tonic. Kernels are utilized medicinally for stomach disorders, as a tannin source which is utilized as a pesticide for use on stored grain. Shells and wood are utilized to produce charcoal. In addition to firewood, trees are logged and utilized for furniture and stocks for weapons (Xu Rongzhang, personal communications). Trees are also incorporated in agroforestry systems for soil conservation and for intercropping with other food and fiber crops. For example, in the P.R.C. bamboo is sometimes grown in association with Chinese hickory.

Ecology

Environmental parameters: Chinese hickory exhibits moderate shade tolerance, especially as a juvenile tree. In its natural habitat young trees grow in the shade of shrub forest and weeds; in fact, they rarely grow well in full sunlight.

Trees possess moderate drought tolerance, growing best on northerly slopes in the wild. Trees growing on slopes with northerly exposures grow more vigorously, produce greater nut yields, produce higher quality nuts, and are a longer lifed than those on drier (usually southern exposures) slopes (5). Trees grown under dry conditions, especially if air temperatures are high, almost always produce poorly filled kernels. The best sites in the wild consist of soils derived from limestone parent materials with a pH of 5.5 to 7.5 (5, 8). Trees grow well at elevations ranging from 50 to 1,100 m above sea level with best production usually occurring between 200 and 900 m in elevation (Li Zhang Ju; personal communication).

Chinese hickory exhibits moderate cold tolerance even though it has buds without scales. Trees can survive winter cold down to at least -20°C. It is supposed that the high levels of tannins found in its naked buds contribute to cold resistance (5).

Growth Characteristics: The species can attain a height of about 30 m with trees frequently reaching 12 m before appreciable flowering. Shoot growth is determinate (growth is not continuous but occurs in flushes), with there being as many as three growth flushes per growing season. These flushes occur in the spring, summer, and early fall. In the wild, tree growth frequently results in a long clear trunk, useful for forest products (5); however, orchard

trees are shorter and are of less value for timber unless they are trained to a central leader.

Chinese hickory is monoecious with three types of flower flusher; these being male, female, and mixed. The spring shoot flush produces female flowers at the shoot apex while male flowers (catkins) are generally borne along the length of the last season's shoot. Flowers of both sexes commonly occur on new shoots; however, the spring flush is most important for nut production, producing about 80% of the nut crop.

Chinese hickory exhibits heterodichogamy with the dichogamy being protandrous and protogynous. Flowers do not differentiate synchronously; accordingly, male flowers begin differentiation from late May to early June, temporarily cease development from early July to early March the following year when development is resumed and completed in early May. This process covers portions of two growing seasons, about 11 months (6). In contrast, differentiation of female flowers begins in early April and terminates in late April, requiring only about 20 days to complete morphological differentiation (6, 8).

The typical phenological progression of trees growing in Linan county (Zhejiang Province) results in trees breaking bud dormancy in early to mid April with flowering in early to mid May. Pollen is generally released over a four day period whereas female flowers are generally receptive over a 5 to 10 day period. There is typically a rather large post-pollination fruit drop that occurs from late May to early June, comprising about 70% of the annual fruit drop. This drop is thought to be due to low concentrations of available assimilates caused by low sunlight associated with the rainy season. Fruit enlargement ends by late July with kernel filling terminating by late August. Nut ripening occurs from mid to late September with leaves abscissing in early November. The existing cultivars require a growing season of about 200 days (Xu Rongzhang, personal communication). Trees produce very well at Hangzhou (Zhejiang Province) where the growing season is about 215 days.

Germplasm

Most of the cultivated production (96%) in the P.R.C. is from seedling trees. This is largely due to the difficulty associated with obtaining successful grafts or buds. The most commonly utilized techniques are whip grafting and ring budding; as a result, the development and proliferation of scion or rootstock cultivars has been severely handicapped. Five scion cultivars have been identified. Rootstocks are either open-pollinated Chinese hickory seedlings or *Pterocarya stenoptera* (wing-nut) seedlings (Li Zhangju, personal communication). The primary scion cultivars are 'Yuanguo' and 'Bianguo' (Fig. 1). These clones have been available for about 100-years-old and represent the majority (about 90%) of the commercial production that is derived from scion cultivars. Most of this production is from 'Yuanguo' (about 60%), with 'Bianguo' comprising a much smaller percentage (30%). The nuts of 'Yuanguo' are round and weigh from 3 to 4.5 g and possessing 44-50% kernel. Depending upon cultural conditions and bearing status, kernels contain from 69 to 72% oil. The nut is

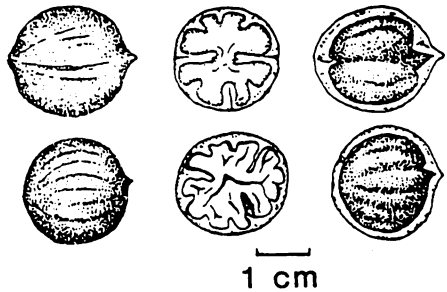

Figure 1. Leading cultivars of Chinese hickory (*Carya cathayensis*): Upper-'Yuaguo'; Lower-'Bianguo.'

easily shelled to give a high percentage of intact kernels. Compared to other cultivars, 'Yuanguo' is considered to be of superior quality, possessing a highly desirable flavor. The secondary cultivar, 'Bianguo,' produces elliptically shaped nuts having three cotyledonary chambers rather than the usual two found in most other cultivars. Kernel quality is similar to that of 'Yuanguo'; however the thick shell makes it difficult to obtain whole kernels upon cracking and also gives a low percentage shellout.

The dichogamy of 'Yuanguo' and 'Bianguo' is protandrous. Since most orchards contain seedlings of diverse genotypes, self-pollination is rarely a problem.

Breeding efforts to improve Chinese hickory cultivars began in the 1960's. This effort encompassed hybridization with several other *Carya* species, such as *C. hunanensis* and *C. illinoinensis*. The primary objective is to produce consistently high yielding cultivars possessing large and high quality nuts. Since Chinese hickory hybridizes with several different *Carya* species, pecan is being used as a male parent in an attempt to obtain the above mentioned characteristics. Hybrids of *C. cathayensis* x *C. illinoinensis* exhibit a metaxenia effect, producing nuts with a higher kernel percentage than occurs in nuts derived from intraspecific crosses (5). The interspecific offsprings (when pecan is the male parent) grow about 12% faster and appear to have more roots than their Chinese hickory parents (5).

Cultivation

The difficulty associated with the propagation of scion cultivars is one of the major factors limiting the cultivation of Chinese hickory; however, this problem is expected to be resolved with further refinement of grafting or budding techniques. Currently utilized clonal propagation methods typically yield a success rate of about 30%. The grafting (whip or cleft grafting) of scion cultivars onto one- or two-year-old seedling trees in mid February to late March results in compound trees that become productive much earlier than that of nongrafted trees. This results in trees fruiting in six rather than the usual 12 years. These trees are utilized to establish orchards at a 3 x 5 m spacing and are thinned to 6 x 5 m as their allotted space is utilized.

Since Chinese hickory is easily stressed by dry soil conditions, many orchards are kept free of weeds and are irrigated to prevent premature fruit abscission and to produce well filled nuts. In the area of Linan, monthly rainfall in July and August is 14 cm and 17 cm, respectively; while evapotranspiration is 20 and 21 cm, respectively. Orchards are typically mulched with grass to conserve water, with most receiving irrigation via furrow or flood systems.

Alternate bearing is considered to be one or the primary horticultural problems associated with Chinese hickory cultivation (Xu Rongzhang, personal communication). It typically becomes a problem after trees have produced fruit for about ten years and becomes increasingly severe as trees age. The result is inconsistent nut production and poor nut quality during the 'on' years. The cause appears to be associated with insufficient assimilate reserves following an 'on' year; hence, assimilate reserves are insufficient for adequate flower development. Alternate bearing is moderated by optimizing nutritional levels and minimizing water stress. Trees are sometimes sprayed with 0.5 kg $(NH_4)_2SO_4$ and 1.0 kg of phosphate per tree in March to promote the initiation and development of female flowers in 'off' years, and 1.5 kg KH_2PO_4 in June or July during 'on' years to compensate for the consumption of K and P by the heavy crop. Trees are also fertilized with 50 kg/tree of organic manure in October.

Chinese hickory occasionally suffers from poor fruit-set due to insufficient pollination. A combination of cool (< 10° C), rainy and humid conditions during the pollination period suppresses pollen dehiscence; resulting in insufficient pollination. Such conditions require supplemental pollination by artificial methods if a good crop is to be attained. The pistil will remain receptive for about 10 days; however, pollination after the fourth day of receptivity results in a decline in fruit-set. While pollen of Chinese hickory can be used for supplemental pollination, it has been observed that pecan pollen may give greater fruit-set and will produce larger and better filled nuts (4).

Pests

There are several endemic insect and disease pests of Chinese hickory growing in the P.R.C. The most limiting are white cloudy spotted borer (*Batocera horsfieldi* Hope) or *Batocera lineolata* Chevrolat), long-tailed greenish silk moth (*Actias selebe* Hubner), and Japanese white birch wooly aphid (*Glyphnia betulae* Koch.). Other pests are *Kurisakia sinocaryaea, Apriona germari, Chelidonium gibbibolle* and *Anoplophora chinopisis*. The most important disease is walnut melanconis dieback [*Melanconis juglandis* (Ell. Ev) Groves].

Commercial orchards in the P.R.C. rarely receive chemical pesticide treatments to control disease or arthropod pests. Pest management is mostly dependent upon resistant germplasm and biological control agents naturally present in the orchard or grove environment.

Summary

The factors limiting the cultivation of Chinese hickory are the lack of development of scion cultivars which can produce regular crops and the inability to propagate available cultivars. This crop is only just now beginning to receive research interest and is still biologically undomesticated. Future efforts in plant breeding or selection will undoubtedly increase the desirability and adaptability of this relatively little-known crop.

Most of the world production of Chinese hickory is within the P.R.C. Since local demand normally exceeds supply these nuts have not become a component of the international nut trade except for exports to Hong Kong, Macau and Japan (Dai Chunnian, personal communication). Until recently there has been very little effort to expand production beyond the native local areas where production comes mostly from groves of wild trees, hence, interest in germplasm improvement and subsequent biological domestication has been minimal. While Chinese hickory is a unique and promising horticultural crop meriting additional efforts to expand its cultivation and domestication, wild germplasm has been greatly reduced due to deforestation. With its excellent nut quality, production potential, inherent genetic variability, strong domestic and increasing international demand, Chinese hickory will undoubtedly be a crop of increasing importance and may eventually become a significant component of the world nut market.

Literature Cited

1. Anonymous. 1535. Annals of Yuhang County.
2. Chang, R. H. and A. M. Lu. 1979. A study of the genus *Carya* nut in China. Acta Phytotaxnomica Sinica 17(2):40-44.
3. Cheng, M. H. and Y. S. Li. 1989. A survey of pecan in Jiande forestry station. Hangzhou Daily. October 31. p. 4.
4. Li, Z. J. 1986. The effect of artificial pollination on fruit set of *C. Cathayensis*. Journal of Nanjiang Forestry University 3:37-43.
5. Li, Z. J. 1989. Summary of twenty-six-years of *Carya* research. Symposium On Carya. pp. 1-9.
6. Li, Z. J. and Q. Qian. 1989. A study of flower bud initiation of *Carya carthayensis*. Symposium On *Carya* . pp. 50-59.
7. Lu, A. M. 1982. On the geographical distribution of the Juglandaceae. Acta Phytotaxonomica Sinica 20(3):258-273.
8. Sun, H. Y. 1987. *Carya* , p. 806-817. *In:* Chinese Academy of Agricultural Science (ed.). Pomology in China. First edition. Agr. Pub. House. Beijing, P.R.C.

9. Sun, Z. J. and S. A. He. 1982. The history, present and prospect of pecan in China. Pecan South 9(5):18-23.
10. Manning, W. E. 1978. The classification within the *Juglandaceae*. Ann. Missouri Bot. Gard. 65:1058-1087.
11. Manchester, S. R. 1981. Fossil history of the *Juglandaceae*. Ph.D. Dissertation, Indiana University, Bloomington.
12. Wood, B. W., J. A. Payne andL. J. Grauke. 1990. The rise of the U.S. pecan industry. HortScience 25(6):594, 721-723.

Fruit Varieties Journal 46(1):22-23 1992

The Tse Li, Tsu Li Dilemma

KIM HUMMER[1]

Abstract

An Asian pear called 'Tsu li' in the United States has a pyriform shape and prominent lenticels. In China this pear is pronounced as "Tse li" with a short vowel sound. The Chinese have another high quality pear, more obtuse to ovate in shape than 'Tse li,' and with less prominent lenticels. This pear is called 'Tsu li.' We are requesting scionwood of Chinese 'Tsu li' be sent to the United States. We need to use the spelling 'Tse li' for the pear that we have so that 'Tsu li' can refer to the Chinese 'Tsu li.'

For many years an Asian pear *Pyrus x bretschneider* Rehder, which has been called 'Tsu li,' has been cultivated in the United States. This pear features a prominently lenticelled skin with a green, ripening to yellow, ground color. The calyx can be persistent in some environments with russetting occurring down the fruit from the pedicel end. The pedicel is offset. The shape of the fruit is pyriform with no distinct neck, similar to 5.6 in the IBPGR Pear Descriptor Table of Fruit Shape (2). The fruit is mounded around the pedicel in the same fashion as 'Ya li.'

Several pear researchers and enthusiasts who have recently traveled to China have reported that the 'Tsu li' they ate in China did not resemble the cultivar. which we call 'Tsu li' in the United States. Professor Shen Dexu of the Department of Horticulture at Zhejiang Agricultural University, Hangzhou, visited in the United States this past fall and helped to clarify the 'Tsu li' dilemma. Apparently, transliterating the Chinese pronunciation and characters into English has caused some difficulty because of short and long vowel sounds. The Chinese have two cultivated pears with similar sounding names, Ts'u li (茬梨) and Tsu li (酉禾梨). Drawings of these pears are presented in "The Variety and Distribution of Pears in China" (1). The large-lenticelled pear (Fig. 1) that we have been growing in the United States as Tsu li is pronounced with a short vowel sound. The word in Chinese sounds like a "TS" followed by an "E" as pronounced in the word "self." The "Tse" syllable is short; and spoken quickly. The pear with the short vowel sound originates from Laiyang, Shandong Province (Table 1). The 'Tsu li' pear with the long vowel sound (Fig.

Table 1. Names and origins of Tse li and Tsu li pears.

Chinese	English	Origin Province	Features
茬梨	Tse li or Ts'u li	Laiyang, Shandong	Pyriform with prominent lenticles
酉禾梨	Tsu li or Su li	Dangshan, Jiangsu	Ovoid with less prominent lenticles

[1]Research Leader and Curator, USDA/ARS NCGR, 33447 Peoria Road, Corvallis, OR 97333.