Yunnan Pecans

L. J. Grauke
Research Horticulturist, Curator
National Collection of Genetic Resources for Pecans and Hickories
10200 FM 50
Somerville, Texas 77879

Introduction

The mandate of the National Plant Germplasm System (NPGS) is to collect from worldwide sources of wild species and domestic cultivars to provide for maximum genetic diversity in each genus. The National Collection of Genetic Resources (NCGR) for Pecans and Hickories acquires, maintains, documents and distributes those collections in relation to the genus *Carya*. There are 19 species of *Carya* worldwide. Thirteen occur in the southeastern U.S, while one (*Carya. palmeri* Sarg.) is endemic to Mexico. Five species are found only in Asia (where one, *C. poilanei* (A. Chev.) J. F. Leroy may be extinct). Current living collections of the NCGR include all of the U. S. and Mexican species, and one of the Asian species (*C. cathayensis* Sargent). A trip was made to Vietnam and China in 1990 for the purpose of collecting most of the Asian species (Grauke et al., 1991). In Vietnam, collections were made of *Annamocarya. sinensis* (Dode) Leroy(a close relative that has also been classified as *Carya sinensis* Dode) and *C. tonkinensis* LeComte. Those collections consisted of only two nuts of *Annamocarya* and a dozen *C. tonkinensis* nuts. They were brought back to the U.S. where they were germinated and contributed samples that have been characterized using molecular genetic procedures (Manos and Stone, 2001; Grauke, 2004). In China, collections were made of *C. cathayensis* and *C. hunanensis*. *C. kweichowensis* has recieved little attention from Chinese scientists since its naming, and accessible stands of the trees were unknown. Logistics of travel prevented collection from known populations of *Annamocarya. sinensis* and *C. tonkinensis* in China. Unfortunately, the material collected during the Chinese trip was retained by our hosts when the collection ended and was not viable when received in the U.S. However, the herbarium materials that were collected are maintained at the NCGR for Pecans and Hickories, and contributed to the evaluation of Chinese *Juglandaceae* in the Flora of China (Lu et al., 1999). We have continued to maintain contact with scientists interested in the exchange of information and germplasm of the *Carya* species. Diverse accessions of pecan [*Carya illinoinensis* (Wangenh.) K. Koch] have been provided to cooperators in China in response to multiple requests, consistent with the NPGS policy of freely distributing plant genetic resources for research, education and crop development to those making valid requests. In 2000, I was invited to visit pecan research programs in Hunan and Yunnan provinces and made the trip with Larry Womack, a Texas nurseryman (Grauke 2000a, 2000b). I was invited by researchers in the Yunnan Academy of Forestry to review the Yunnan Pecan Development Program that is evaluating the use of pecan in that region. I accepted the invitation and made the trip Dec. 8-17, 2004. This report documents that trip.

Geography and Climate

Yunnan is the most southwestern province of China, bordering the Chinese provinces of Guangxi, Guizhou, Sichuan and Tibet, as well as the countries of Myanmar (Burma), Laos and Vietnam (Fig. 1). The Tropic of Cancer, separating tropical from temperate climatic zones, crosses southern Yunnan province. The western portion of the province is characterized by mountains that run almost north to south, transected by a number of major rivers. Beginning with the westernmost, the Nujiang river originates on the Tibetan Plateau, cuts south across western Yunnan and becomes the Salween River in Myanmar. The Lancang Jiang river originates on the Tibetan Plateau, cuts southeast across western Yunnan and becomes the Mekong River of Vietnam. The Mekong is one of the world's major rivers, being the 10th longest in the world. The Jinsha Jiang originates in Qinghai province, cuts southeast across Sichuan into Yunnan province where it turns 180 degrees, and after several twists, becomes the Yangzte River. The Yangzte is the longest river in Asia and the third longest in the world, after the Nile and Amazon. The Salween, Mekong and Yangzte rivers come within 40 miles of each other and run parallel in northwestern Yunnan Province. The region is rich in animal and plant diversity, matching the diversity of its climate and terrain. The area of the Three Parallel Rivers of Yunnan was named a World Heritage Site by United Nations Educational Scientific and Cultural Organization (UNESCO) (World Heritage Committee, 2003), because it "is the area of richest biodiversity in China and may be the most biologically diverse temperate region on earth."

Yunnan province also has a rich history, having maintained independence from Central China in the 6th -9th century as the Nan-chao kingdom. The king of the Nan-chao maintained court at the ancient city of Dali, now an international tourist destination. Dali is situated with the Diancang Shan mountain to its west and Erhai Lake to its east (Figure 2). Erhai Lake is a natural lake created by the Lancang Jiang river. It drains from the south and joins several tributaries to become the Mekong River. Just to the west of the Diancang Shan is the city of Yangbi, home of the Economic Forest Improved Variety Research Extension Center of the Yunnan Academy of Forestry, the center of the pecan evaluation program.

Monthly average temperatures recorded at Dali, Yunnan are compared with pecan sites in the United States (Fig. 3). Pecan growing sites in the southern U. S. (Albany, Georgia west across Oklahoma and Texas to Visalia, California) have similar average monthly temperatures. Average monthly temperatures at Burlington, Iowa are lower than at other U.S. sites throughout the year. Winter temperatures in Dali are comparable to those experienced in Brownwood, Texas, and Albany, Georgia, but summer average monthly temperatures are much cooler than in any U.S. pecan growing area.

Temperatures actually experienced at a particular site in Yunnan will be greatly influenced by elevation, and decrease with increasing elevation. Fitzgerald (1940) noted that precipitation increases with elevation in Yunnan, and results in a vegetation change:

> "As one goes west in Yunnan the ranges are steeper and higher and the valleys more deeply cut; the rainfall is therefore heavier, since Yunnan receives the Indian monsoon from the south-west. Consequently the snow-line is lower in western Yunnan than in the Tibetan marches to the north-east. Ranges in eastern Yunnan like the Ting Hsi Ling at 10,000 feet are only occasionally covered with

> snow, but the Kao Li Kung just east of T'eng Yueh, 200 miles to the west, which is about the same height, is often covered with snow for months on end. The fact that the mountain tops receive far more rain than the plateau causes a curious inversion of the ordinary expectation that as one climbs higher the vegetation will be thinner and stunted. In Yunnan, trees grow higher as one ascends. At 6000 feet, the level of the plateau, there are only the screw pines and dwarf azalea scrub, but at 10,000 feet there are large deciduous trees like chestnuts, tree rhododendron, cedars, and several kinds of what appear to be ilex. Between 10,000 and 15,000 feet there is dense rain forest of magnolia, cedar, bamboo, and rhododendron, with the ilex and certain deciduous trees also". (p. 12)

Such changes in temperature and precipitation with elevation are the foundations of this region's rich diversity of plants.

Comparison of average monthly rainfall also shows dramatic differences between Yunnan and U.S. sites (Figure 4). The total amount of rain received annually in Dali,Yunnan (1100 mm/yr) is less than that typically received in Albany, GA (1262 mm/yr). However, Dali receives over 70% of its yearly rainfall in the months of June to September, a "monsoon" pattern. Georgia receives relatively uniform precipitation throughout the year, a pattern typical of the Eastern U.S. The two Texas sites and Ardmore Oklahoma share a pattern of spring and fall rainy periods, with drier periods in the winter and summer. Burlington, Iowa receives rain uniformly across spring, summer and fall, with dry winter. That pattern is reversed in Visalia, California where winter rains bracket a dry summer.

Rainfall is critical to survival, growth and production of pecan, and when it is in short supply, as in Visalia California, supplemental irrigation is required. The greatest disease challenge to pecan is from pecan scab, caused by *Fusicladium effusum* G. Winter. Scab disease pressure increases with increasing rainfall. The USDA Pecan Breeding program maintains worksites at Brownwood and College Station, Texas. Our Texas sites show the greatest similarity in both distribution and amount of rainfall among all sites compared (Fig. 4). Despite that similarity, we notice generally reduced disease expression of the same cultivars grown at our Brownwood site when compared to the College Station site, which we attribute to the more humid conditions at the latter site. Scab disease pressure is very great in Albany, Georgia, where wetness throughout the summer often contributes to the early onset and continuation of scab disease. It will be interesting to observe disease expression in pecan cultivars in Yunnan which receives high rainfall throughout the summer and into autumn.

Itinerary

I arrived in Kunming, Yunnan Province on Dec. 10, 2004, and was welcomed by Director Xi Xue Liang and his team- Mr. Liao Yong Jian, Mr. Zou Wei Lie and our capable driver, Mr. Zhao Chuan. On Saturday, Dec. 11 we drove to Yangbi, Dali Province, to visit the Experiment Station. At the Station, we were met by Director Yang, several of her students, and the officers of Yangbi city. We toured the collection of pecan cultivars established from graftwood provided in several exchanges since 1998 (Fig. 5). They noted that in some seasons, they have problems with a leaf-eating stinging caterpillar of the Casuarina moth (*Lymantria xylina* Swinhoe), which is related to the

gypsy moths (*Lymantria dispar* L.). They reported control of the moth using sprays of diesel oil and deltamethrine.

We made a quick tour of a nursery where they plant seed of 'Shoaxing', a pecan seedling selected from Zhejiang Province (where the city of Shoaxing is located)(Fig. 6). Within the nursery were 30,000 seedlings that had been grafted to 'Jinhua 1' (Fig. 7). Jīnhuá means "golden brilliance in Chinese, and is the name of another city in Zhejiang Province, where this pecan selection originated. Trees were grafted using the modified one-bud inlay graft we had first seen in Hunan during our trip in 2000 (Grauke, 2000a). Director Xi claims 90+% success with this grafting technique. According to Xi, there are currently 10,000 mŭ (1 mŭ = 0.0667 hectares or 15 mŭ /Ha) of pecans in Yunnan Province and they target 20,000 (1,333 Ha). By comparison, there are 5 million mŭ of the local walnut, *Juglans sigillata* Dode, in Yunnan (333,333 Ha).

That evening, we walked through the old city of Yangbi, to the suspension bridge over the Yangbi River (Fig. 8). Iron chain suspension bridges were first developed in this area by General Shi Wansui and the military engineer Su Rong, around 590 AD (Ronan, 1995). The ancient cobblestone road leading to the bridge is part of an ancient caravan route along which silk was carried into Burma (Fitzgerald, 1940). We walked past a walnut processing house, where the local walnuts are cracked and shelled by hand. Shells were being used as fuel for cooking.

On the morning of Dec. 12, we toured the Experiment Station, looked at the grafted trees that had been established from graftwood we had sent, and discussed their performance. We discussed the influence of early season rainfall on nut size, and late season rainfall on nut fill. The low rainfall they receive in early spring may need to be supplemented with irrigation. They have had defoliating diseases in August, probably associated with the high summer rains. The cultivars that they rated high included 'Shawnee', 'Sioux', 'Mississippi 10', 'Surprize', 'Caddo', and 'Sumner'. When I mentioned 'Pawnee', Director Xi enthusiastically commented that "'Pawnee' is good!" However, I did not see yield data or other evaluation information.

In the afternoon, we drove south to Wa Chang, where their cooperator, Mr. Wang, grows trees on steep terraces, intercropping with broad beans and wheat. Corn stalks were used to reinforce the terraces. Mr. Wang had many mature trees of the local walnut, *Juglans sigillata*, some showing scars from tree wounding that they believe increases production (Fig. 9). Xi commented that the precocity and productivity of young pecan trees gives them an advantage over the walnut. We visited nurseries where seedling trees were transplanted one day, then grafted the next, according to Mr. Liao. In the nurseries, the primary cultivar being propagated was 'Jinhua 1'. That evening, we returned to Xia Guan for the night, but made an evening trip to the ancient city of Dali.

The next day, Dec. 13, we had meetings with officials from the Academy of Forestry at a cooperator site in Bei Dou. The site was again on a steep hillside, and several pecan cultivars were planted on terraces. Cultivars being grown included 'Jinhua 1', 'Shaoxing', 'Pawnee', 'Baker', 'Shawnee', 'Choctaw', 'Caddo', and 'Mahan'. Despite the challenging terrain, trees had made 3 feet of growth during the current season. Trees were up to 10 years old, with the oldest being 'Jinhua 1'. Those had begun to bear and yields were evidently very good (up to 27 kg or 60 lbs per tree, according to my hosts). The farmer, Mr. Cheng Xue Xian and his wife were so excited about the quantity and quality of their new crop that they had planted some of the nuts to grow

more trees. The lady of the farm had problems with headaches and considered pecans a remedy. We saw evidence of the girdling larva we had seen in 2000 at the Experiment Station, similar to that caused by Cossid insects.

I encouraged my hosts to be aware of the value of their native *Carya* resources, and to incorporate them in their work, possibly as rootstocks for pecan. The information concerning native tree uses by indigenous people constitutes a very valuable resource that should not be ignored in the rush to cultivate an introduced crop. Knowledge of the pests and predators challenging their native *Carya* species may help them anticipate and address challenges with pecan. Furthermore, the variation in climate that produced the genetic diversity of this region may result in relatively narrow bands of cultivar adaptation. The influence on patterns of bud growth in the spring, flowering, leaf drop and crop maturation in the fall will be very interesting to observe as they evaluate pecan cultivars and may complicate deployment of materials. Field testing is the foundation of any good program, and the Yunnan Pecan program was attempting the difficult job of establishing diverse cultivars in the area and monitoring their progress.

I was concerned about the amount of 'Jinhua 1', or any single cultivar being used in isolation, and talked to my hosts about pecan's patterns of heterodichogamous flowering. The separation of male and female bloom within a tree necessitates another cultivar with complementary bloom to insure cross pollination and maximum production and nut quality (Grauke and Thompson, 1996). On May 17, 2000, 'Jinhua 1' trees at the Yangbi station had just begun shedding pollen (with few catkins fully spent) and pistillate flowers were receptive (mostly past). I had rated it as protogynous in flowering habit. We suspected that 'Jinhua #1' was a 'Mahan' descendent, if not a progeny, based on nut shape. Using our microsatellite primers (Grauke et al., 2003) I was able to confirm that the molecular profile of 'Jinhua #1' is consistent with 'Mahan' parentage. 'Mahan' was one of the first grafted cultivars brought into the Zhejiang province of China (Sun and He, 1982), where 'Jinhua 1' and 'Shaoxing' both originated. Pecan flowers mature at different times in a system that is controlled by a single gene (Thompson and Romberg, 1985). Trees with a dominant gene are protogynous, with female flowers maturing before male pollen is shed. Trees having two recessive genes are protandrous, and shed pollen prior to pistil receptivity. 'Mahan' is the only homozygous dominant pecan cultivar we know, having two dominant alleles for protogyny. As a result, all of 'Mahan's' progeny are protogynous. If a large number of the seedlings being evaluated in China are 'Mahan' progeny, there would be a disproportionate number of protogynous seedlings. This might increase the importance of monitoring bloom overlap among deployed cultivars and insuring that there is opportunity for cross pollination.

After completing our discussions in Bei Dou, we returned to the ancient city of Dali for the evening. The next day (Tues, Dec. 14), we returned to Kunming.

On Dec. 15, we visited the offices of the research team at the Yunnan Academy of Forestry. They collect vouchers of nut samples to represent the trees in their test blocks just as we do, allowing verification of cultivar identity. That afternoon, we visited the beautiful "Stone Forest" east of Kunming where limestone deposited by an ancient sea was exposed to the surface and eroded by wind and water to form beautiful karst formations (Fig. 10).

On Thursday, Dec 16 we toured the plantings at the Academy of Forestry in Kunming, seeing more evidence of the propagation skill of our hosts, where 'Jinhua 1'

was again being exclusively propagated (Fig. 11). In the afternoon, I gave a presentation concerning our development of molecular markers for use in characterizing diversity within the *Carya* genus. Among the pictures were slides of the low growing trees in our provenance orchards that originated from Ixmiquilpan, Mexico. They are dramatically shorter and more spreading than the vigorous, upright trees from Jaumave, Mexico. Director Xi was very interested in the low growing trees, a trait he considered valuable for keeping the productive canopy low to facilitate harvest on the steep slopes of Yunnan. We had good discussions that included the materials we would like to exchange the following year. In the afternoon, we visited the Botanical Gardens of the Chinese Academy of Science. On Friday, Dec. 17, my hosts escorted me to the airport and I returned to Texas.

Summary

This trip to Yunnan was a valuable opportunity to see the development of a pecan industry at its very early stages. Since pecans are native to North America, the Yunnan pecan program is based on genetic materials provided to Chinese cooperators over the years. By maintaining such cooperation, we have the opportunity to learn more about the adaptation of pecan in particular, and the walnut family in general, to that region of the world. Hopefully, we will be able to obtain better representation of the native *Carya* species of southwestern China. Such cooperation benefits all of us.

There are many interesting questions that must be addressed for the Yunnan pecan industry to succeed. Which cultivars will perform best in Yunnan, and how should they be deployed for adequate returns? Their heavy utilization of 'Jinhua 1, a Chinese seedling selection, is noteworthy. Patterns of dichogamy within and between cultivars should be carefully observed to insure maximum productivity. What pest problems will plague the crop? Can they be overcome by appropriate cultivar selection or by management? There is no question about the enthusiastic reception pecan nuts have received among the people of Yunnan who have tried them. I was surprised to see the growth and to hear of the precocity and productivity of pecans on the steeply sloped sites being tested. If pecan succeeds in Yunnan, it will be under much different circumstances than it is grown in the United States. The industriousness of my hosts and their cooperators suggests that this introduced crop will be given a fair chance to succeed. It is important that the native trees of *Carya* and *Juglans* currently growing in that unique environment, as well as the rich folk history of their utilization, not be displaced or jeopardized in the excitement to develop the new crop. I hope my visit to Yunnan contributed to that end.

Literature cited.

Backus, Charles. 1981. The Nan-chao kingdom and Tang China's southwestern frontier. Cambridge University Press, New York. pp. 224.

Fitzgerald, C. P. 1940. Yunnan Burma Road. The Geographical Journal 102:49-56.

Grauke, L. J. 2000a. The developing pecan industry in China. Pecan South. 33:1, 20-21 (cover photo).

Grauke, L. J. 2000b. Pecan production in China, 2000: A report to the Crop Germplasm Committee. <http://extension-horticulture.tamu.edu/carya/chinareport/chinareport.htm>

Grauke, L. J. 2004. Vulnerability of Carya. http://www.ars-grin.gov/npgs/cgc_reports/CaryaVulnerability2004.

Grauke, L. J., Iqbal, M. J., Reddy, A. S., and Thompson, T. E. 2003. Development of Microsatellite DNA Markers in Pecan. J. Amer. Soc. Hort. Sci. 128(3):374-380.

Grauke, L. J. and Thompson, T. E. 1996. Variability in pecan flowering. Fruit Variety J. 50(3):140-150.

Grauke, L.J.; Wood, B.W.; Payne, J.A. 1991. Genetic resources of Carya in Vietnam and China. Annu. Rpt. N. Nut Growers Assn. 82:80-87.

Lu, Anmin, Donald E. Stone, and L. J. Grauke. 1999. Juglandaceae. p 277-285. In Wu, Z. Y. and Raven, P. H. (eds) Flora of China, Volume 4, Cycadaceae through Fagaceae. Co-published by Science Press (Beijing) and Missouri Botanical Garden Press (St. Louis).

Manos, P. S. and D. E. Stone. 2001. Evolution, phylogeny, and systematics of the Juglandaceae. Ann. Missouri Bot. Gard. 88: 231-269.

Ronan, C. A. 1995. The shorter science and civilisation in China: An abridgement of Joseph Needham's orginal text. Vol. 5: civil engineering. New York: Cambridge University Press, 1995.

Sun, Z. J. and S. A. He. 1982. The history, present and prospect of pecan in China. Pecan South 9(5):18-23.

Thompson, T. E. and Romberg, L. D. 1985. Inheritance of heterodichogamy in pecan. J. Heredity 76:456-458.

World Heritage Committee. 2003. Decisions adopted by the 27th session of the World Heritage Committee in 2003. WHC-03/27.COM/24 (available online at: http://whc.unesco.org/archive/2003/whc03-27com-24e.pdf

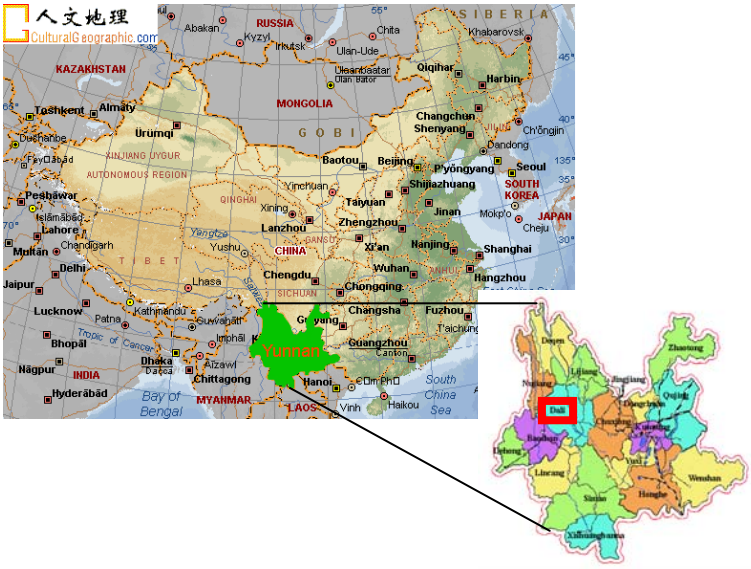

Figure 1. Location of Yunnan Province in Southwestern China. Inset shows districts of the province, with the area of the Dali district visited in this trip within the square.

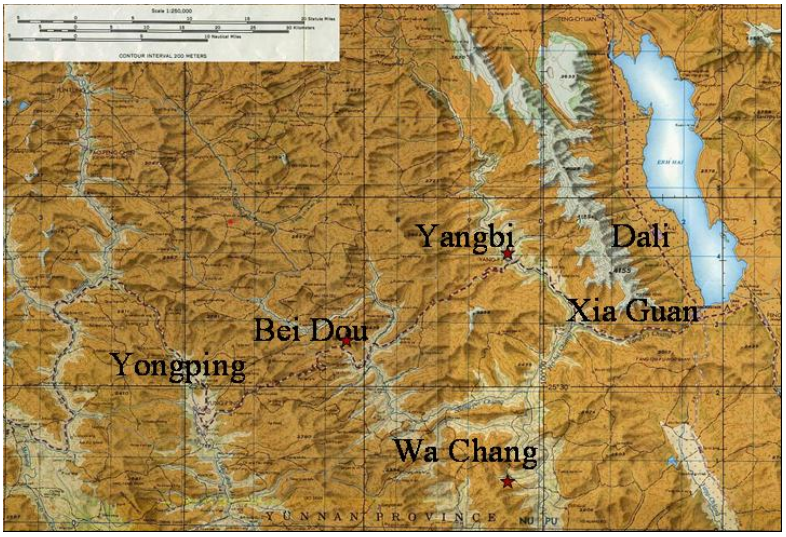

Figure 2. The region of Yunnan Province where pecan test sites were visited, Dec. 2004.

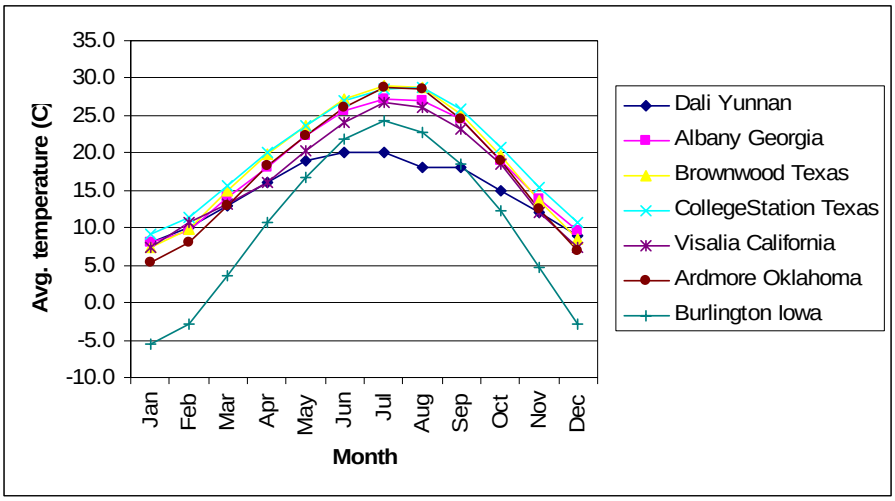

Figure 3. Monthly average temperatures recorded at several sites where pecans are grown.

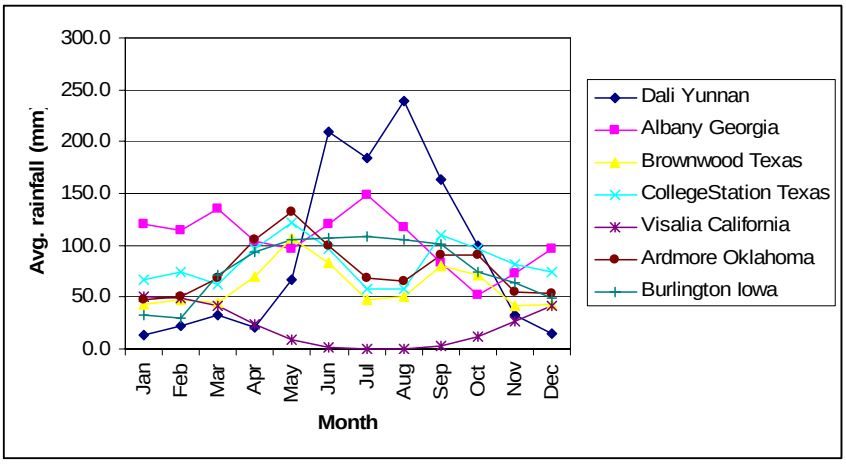

Figure 4. Monthly average rainfall recorded at several sites where pecans are grown.

Figure 5. Pecan collections at the Yangbi Experiment Station, with hosts. From left: student, Zou Wei Lie, Liao Yong Jian, Director Xi Xue Liang, Director Yang, students.

Figure 6. Planting seed of ‘Shaoxing’ pecan at the Yangbi Experiment Station, Yunnan, Dec. 11, 2004.

Figure 7. Nut sample of ‘Jinhua 1’ pecan seedling selection from Zhejiang province.

Figure 8. Chain suspension bridge over the Yangbi River, Yangbi, Yunnan, Dec. 11, 2004.

Figure 9. Walnut (*Juglans sigillata*) trees, Wa Chang, Yunnan, Dec. 12, 2004, showing scars from trunk wounding thought to increase production.

Figure 10. Karst formations in the Stone Forest, Yunnan, Dec. 15, 2004.

Figure 11. Director Xi Xue Liang at pecan nursery, Yunnan Academy of Forestry, Kunming, Dec. 16, 2004.